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RECESS FASTENERS

TECHNICAL OPERATIONS GROUP
DEPUTY FOR ENGINEERING

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Final Report for Period 1 September 1976 to 1 December 1977

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DEPUTY FOR ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This report covers four tasks. A recess fastener test method is developed and the results of tests showing the affect of parameters and comparative recess performance are reported. The results of an investigation into the factors affecting removal torque are reported. An analytical method for determining fastener tensile strength as a function of recess depth is described. Finally, the results of a field data gathering effort to measure torque, end load, and tool angle during installation and removal of fasteners are detailed.

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FOREWORD

This report describes an in-house effort conducted by personnel of the Aeronautical Systems Division, Air Force Materials Laboratory, and Air Force Flight Dynamics Laboratory. In the Aeronautical Systems Division, the work was carried out under Project ASDD 0191, "Fastener Technical Data Base".

The work reported herein was performed during the period of 1 September 1976 through 1 December 1977, under the direction of the primary author, Mr. E. J. Raimondi. The report was released by the author in January 1978.

The author wishes to thank Capt E. Bannink, 1st Lt G. Boman, and Mr. F. Sandow of the Air Force Flight Dynamics Laboratory, who were responsible for conducting the tests described in Section 2 and Section 5, and are also contributing authors to those sections; Dr. V. Venkaya and Dr. J. Eimermacher of the Air Force Flight Dynamics Laboratory, who performed and reported on their analytical effort described in Section 4; Mr. R. Urzi of the Air Force Materials Laboratory, who conducted the tests described in Section 3 and also contributed as an author to that section; Mr. R. Stewart, Mr. W. Kinzig, Mr. V. Battenberg, and 2nd Lt K. Bauman of the Aeronautical Systems Division, who supported conducting the tests described in Sections 2 and 5. Lt Bauman is also a contributing author to Section 5.

Many Government and Industry organizations also supported these tests. Some provided fastener and bits for our trials and verification tests. Others provided needed materials or services under contract. At least 15 agencies or companies have been involved - a list considered by the author too long to list. Also, the fear of inadvertently omitting someone would be deeply regretted. To each of these, a grateful thank you.

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INTRODUCTION

Over the years, many complaints have been received by the Aeronautical Systems Division on the service failures of aircraft fastener internal wrenching systems. A synthesis of the problem showed that the reported failures were concentrated on the smaller size fasteners (3/16" - 5/16" shank diameter) installed in frequently removed panels, and the failures usually occurred when removal of the screws was attempted with a speed wrench.

The reason failures are reported on removal is that it requires a machinist to take the failed screw out, and this creates a delay in returning an aircraft to operational status. Installation failures usually occur before the screw is completely seated; and it can easily be removed and replaced by the aircraft mechanic, therefore it is almost never reported.

Various factors were identified as having an impact on the problem; from the causes of high removal torque to low recess torque capability and from both tool quality and proper tool selection to various human factors. However, there is yet another and very basic problem - there is no standard test method to realistically evaluate recess performance. A program was undertaken using the resources of the Aeronautical Systems Division, Air Force Flight Dynamics Laboratory, and Air Force Materials Laboratory to investigate the aircraft fastener area. The test program had four objectives: (a) develop a test method that would allow a determination of recess performance under the effects of various parameters; (b) determine the removal-installation torque ratio and the factors affecting this ratio; (c) an analytical determination of the relationship between tensile strength of the fastener as a function of recess depth; and (d) present the results of a field data survey which measured applied torque, end load, and tool insertion angle.

This report is presented in four parts. Each part deals with one of the four objectives cited above.

SECTION II

DETERMINATION OF A RECESS FASTENER TEST METHOD

In order to understand recess design and performance characteristics, engineers and designers rely upon tests. As unusual as it may seem, a standard recess performance test method does not exist. Tests have been conducted on recesses in the past. However, the test procedures and methods of evaluation have not been consistent. More often than not, they were conducted under conditions that were ideal for the recess such as no offset angle on the driver, no paint in the recess, etc.; and as a result, they did not adequately predict actual service performance. As a result, the choice of recess style (Torq-Set, Hi-Torque, Phillips, etc.) has been largely by emotion and bias as opposed to the careful weighing of technical merit.

This section describes the development of a test method that provides data consistent with Air Force service experience. The parameters of paint in the recess, offset driver angle, the use of undersize drivers, soft drivers, and their combinations were evaluated. Five recess styles were evaluated: Phillips, Torq-Set, Hi-Torque, Torx, and Tri-Wing. The fastener size tested was 3/16" shank diameter, flush tension head, A286 stainless steel with a tensile stress of 160,000 psi.

1. Test Equipment

The test machine was specifically fabricated for this test program. It was designed to (a) measure the torque applied to a recess by a driver bit; (b) allow a pre-test determined constant end load to be applied (end load is the force acting through the longitudinal axis of the fastener/driver to keep the driver in the recess); and (c) allow a pre-test driver off angle to be applied with the driver and recess mated. The test machine is shown in Figures 1 and 2.

End load was applied by a mechanical dead weight acting through a cable, pulley, and bell crank system. The weight was reacted by the fastener mount. The mount was hinged at the four corners to allow horizontal motion and permit the fastener to back away from the driver. This was done to duplicate the driver "cam-out" action. The fastener itself was held firmly fixed in a chuck and did not rotate. The actual end load was measured prior to mating the fastener and driver. This was accomplished by inserting a load cell at the chuck head as shown in Figure 2.

The base of the equipment holding the handle was adjustable to allow an offset angle to be introduced. The protractor to measure the off angle can be seen in Figure 2.

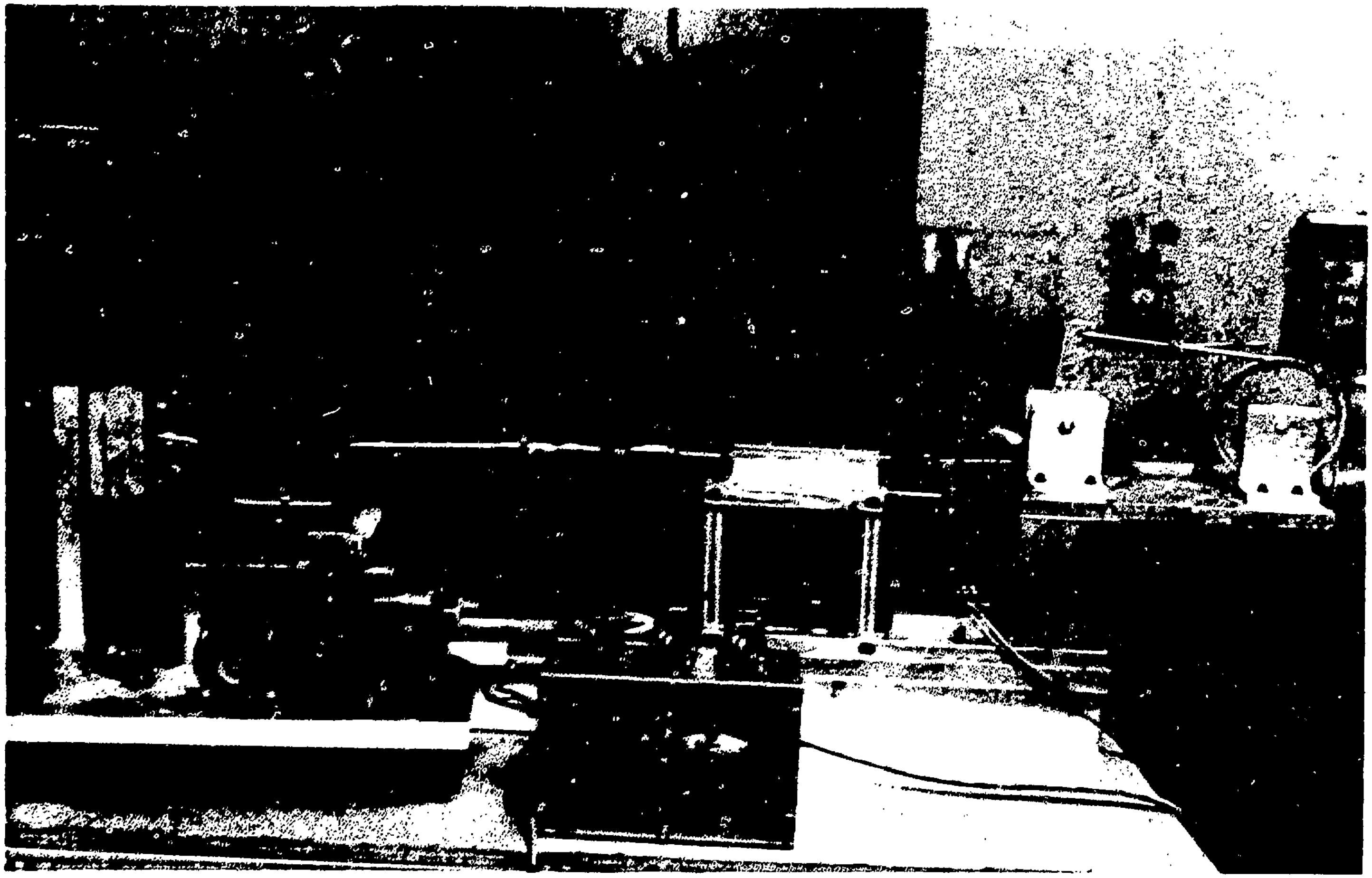


Figure 1 - Test Equipment

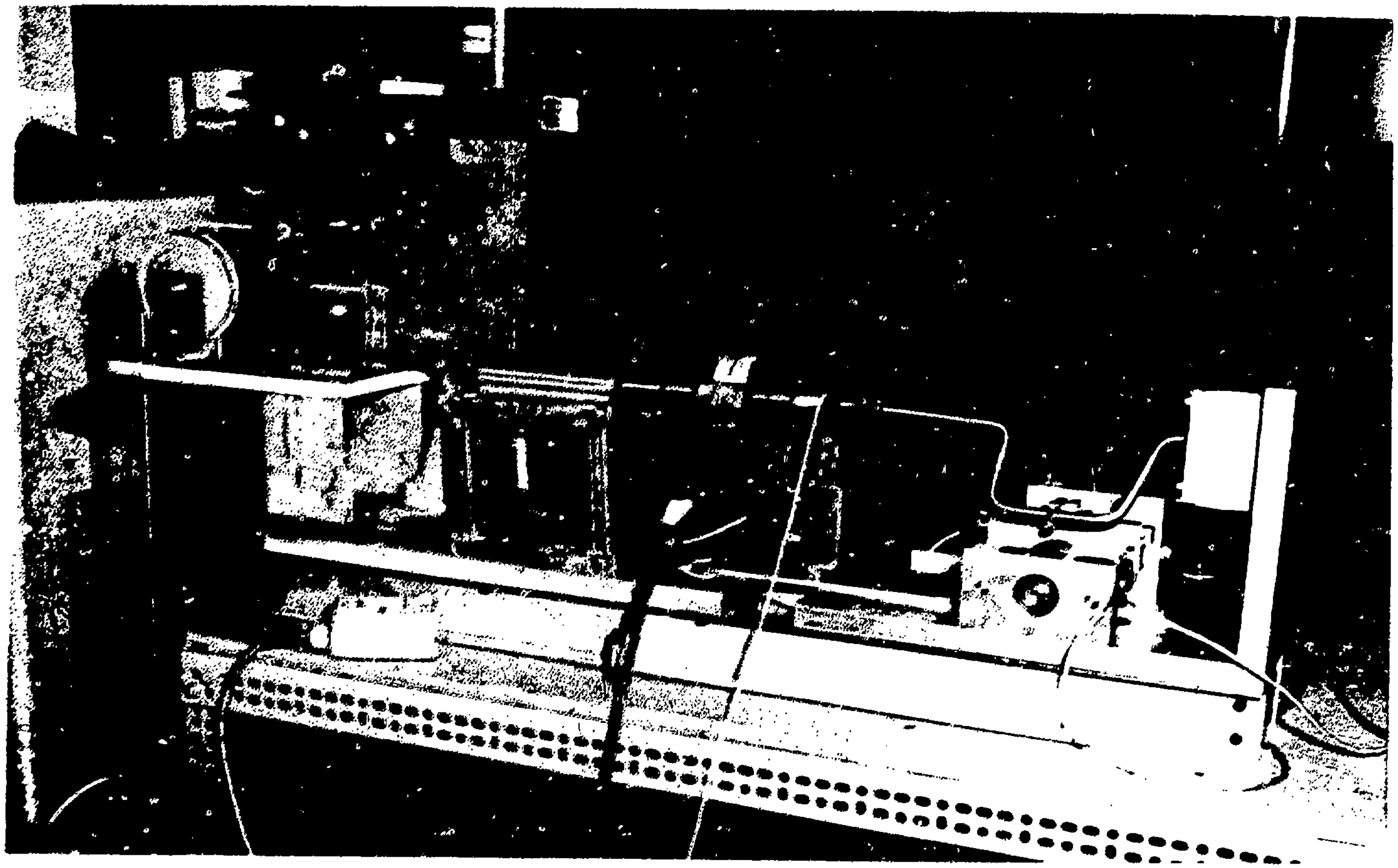


Figure 2 - Test Equipment

2. Test Procedures

The initial test philosophy was based on the belief that recesses failed due to gradual wear or fatigue. It was planned to display the results in a series of curves similar to S/N curves but using torque levels rather than stresses vs the number of cycles. Data was to be obtained from various end loads, with and without paint in the recesses, with and without the bit at an offset angle, with hard bits and soft bits, with undersized bits and with worn bits. A summary of the preliminary test results (Table 1) showed that the recesses did not fail. A failure is defined as the inability of the recess to sustain the desired torque levels.

Despite the varying conditions tried, the recesses continued to function at the imposed torque levels. Even under relatively severe conditions as shown in the final line, the recess did not fail. Data was also taken on the corresponding bit performance. The bits were used until the desired torque could not be obtained. Then, a new bit was introduced. As long as the recess could support the torque, the test continued. On the average, the bits were replaced every 60 cycles of torque application.

Two conclusions can be obtained from these tests. The first concerns the focus of attention in our initial attempts. Here, the focus was on the recess alone and ignored the performance of the bit. Yet, the recess and the bit are not independent of each other; they must be physically compatible and their system performance determines their ultimate utility. Our first conclusion then is that further tests must be concerned with the system characteristics of each recess style.

The second conclusion concerns the failure mode to be considered. The tests showed the gradual wear or fatigue in the recess did not occur at the rate anticipated before the tests began. The lack of failures also indicated that this failure mode is not the one being experienced in the field where failures occur at much more frequent intervals. Careful consideration of the conditions existing in the field leads to the observation that field failures occur "instantaneously" during installation or removal. That is, the conditions imposed (torque, angle, end load, etc.) are sufficient to cause a static failure in the recess or bit or both. The static failure is the primary failure mode governing the performance of a recess system.

The test procedure that was actually used then took advantage of both considerations: (a) it would test the recess plus bit as a system, and (b) it would focus on the static failure mode for the system. Before describing the specific procedures, an overview of the anticipated results will be given.

TABLE 1

INITIAL TEST RESULTS

RECESS STYLE	END LOAD LBS	TORQUE IN. LBS	OTHER CONDITIONS	RESULTS
A	3.3	35		333 CYCLES NO FAILURES
B	4	35		100 CYCLES NO FAILURES
C	75	45		125 CYCLES NO FAILURES
D	40	55	7° ANGLE	250 CYCLES NO FAILURES
E	4	35		100 CYCLES NO FAILURES
A	100	55	PAINTED 7° ANGLE	2000 CYCLES NO FAILURES

From an overall perspective, the test method used will determine the maximum torque (i.e., failure torque) that a recess-drive system can produce. These results are summarized as shown in Figure 3.

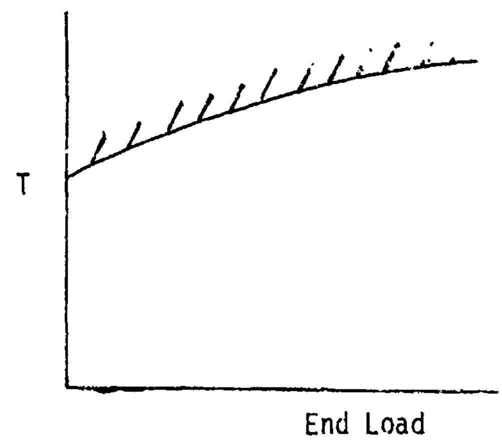


Figure 3

Of all the parameters to be investigated, torque, end load, and angle are the three primary variables common to all other test parameters. The torque, which is the primary performance parameter, is plotted in the vertical axis. End load is plotted on the horizontal axis. Angle and other parameters can then be shown as a family of curves. In Figure 3, the curve shown is the maximum torque that can be obtained from a new recess/bit pair. The cross hatching indicates that there are no combinations of torque levels that can exceed the level determined. The curve then is the set of points at which a failure occurs. Below the curve, a static failure does not occur. This is true by the very nature of the data itself. If a static failure occurs at X_1 inch pounds, then a static failure will not occur if $X_2 < X_1$. When we are applying torque and end load at a level which is below the curve, one would not expect to see material failures. The expectation would be that even repeated torque applications below the maximum would not result in failures. This observation was confirmed by our initial test results.

Determining a characteristic maximum performance for the recess system (recess and bit) for each parameter of interest can be easily accomplished. Our common knowledge that paint in the recess affects the levels of torque can now be quantified by testing to determine the maximum torque developed and compare it to the unpainted results.

This now is only part of the answer. Testing for parametric conditions of paint, undersize drivers, and off angle bit insertions can show how torque capability is degraded by typical field conditions. But the crew chief in the field will normally continue trying to remove a fastener once having failed to do so. This poses the question of how much torque remains after the first failure was imparted to the recess system.

The laboratory testing can also simulate this by subjecting the same recess and bit combination to a second determination of maximum torque capability. The results expected are shown in Figure 4.

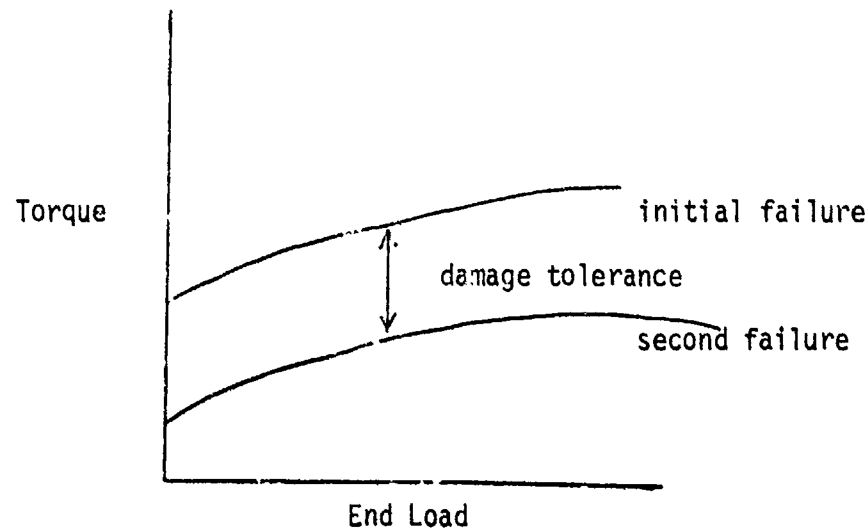


Figure 4

The expectation is that once a failure has occurred the remaining capability of the recess/bit combination would be less than when new. Again, the degradation for various parameters of interest can be determined. If the second failure torque levels are less than that required for removal, the crew chief would not be able to remove the fastener.

Another perspective on these anticipated results is that the gap between the first and second failure levels is a measure of the damage tolerance of the recess design. For a relatively small gap, one would conclude that the recess design was one that degraded slowly. This design feature is highly desired because it allows the best chance of removal of the fastener even though it had been once failed. A recess design that did not offer a significant second failure capability would be of less practical utility because the fastener would be less likely removed as compared to one with a higher second failure torque capability.

In utilitarian devices, damage tolerance designs are universally preferred. It is a fundamental characteristic of good design practice. For example, our automobile engines are highly resistant to damage and off optimum conditions. They run reasonably well in spite of eroded valves, fouled plugs, poor fitting rings, etc.

The testing procedure that was then used tests for and determines the recess performance in terms of its damage tolerance characteristics and maximum torque capabilities for a variety of parametric conditions.

The procedure followed the following steps.

a. The fastener was placed in the fixture and secured. This insured that the fastener did not rotate when the torque load was applied.

b. The required angle was set on the test fixture.

c. The load cell was inserted and end load applied and measured. The load cell was removed.

d. The driver bit was mated with the recess of the fastener.

e. The end load was applied as for the test condition.

f. With the bit mated to the recess and the end load applied (but no torque applied), the instrumentation was calibrated to zero.

g. The torque was slowly applied until either:

(1) the bit broke; or

(2) the driver backed out of the recess so that torque was no longer being applied; or

(3) the maximum torque had been reached as evidenced by a decrease in torque.

h. Using the same fastener and bit and rotating the driver in the same direction as before steps (c) through (g) were repeated.

The actual test matrix for various parameters is given in Table 2.

Test Specimens

All of the fasteners were procured at the same time from the same source. The material was A286 stainless steel, heat treated to 160 Ksi tensile stress and in the 3/16" shank diameter size. The fasteners were all made from the same lot of material and heat treated at the same time. The only difference from a physical point of view between the fasteners was the recess.

TABLE 2

TEST MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Style A	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Style B	X	X	X	X	X	X											X	X	X	X	X	X			X				X			
Style C	X	X	X	X	X	X											X	X	X	X	X	X			X				X			
Style D	X	X	X	X	X	X											X	X	X	X	X	X			X				X			
Style E	X	X	X	X	X	X											X	X	X	X	X	X			X	X		X	X			
Angle	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	7
Size (Correct/Small)	C	C	S	S	C	C	S	S	C	C	S	S	C	C	S	S	C	C	S	S	C	C	S	S	C	C	S	S	C	C	S	S
Hardness (Hard/Soft)	H	H	H	H	S	S	S	S	H	H	H	H	S	S	S	S	H	H	H	H	S	S	S	S	H	H	H	H	S	S	S	S
Bit Condition (New/Worn)	N	N	N	N	N	N	N	N	W	W	W	W	W	W	W	W	N	N	N	N	N	N	N	N	W	W	W	W	W	W	W	W
Paint (Yes/No)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

NOTES:

1. All first failure test performed at four end loads (1.3, 5.0, 10.0, and 20.0 lbs.).
2. Second failure tests performed at 10, 20, 40, and 60 lb. end loads.
3. Four tests (repeats) accomplished at each end load for the Style A recess with the exception of tests 9, 10, 25, 28, and 30 where three repeats were done at each end load.
4. Three tests (repeats) accomplished at each end load for the other recesses except for test 29 where only two repeats were done at three end loads.

As with the fasteners, all the tool bits were also purchased at the same time from the same source. In this case, the tool material was QQ-T-570, type S2 alloy steel. Because one of the parameters to be investigated for recess performance was the relative tool hardness, the tools were made to two hardness conditions. The "hard" tools were 60-62 Rockwell "C" hardness, and the "soft" tools were 45-48 Rockwell "C" hardness. Otherwise, the same lot of material was used and the same heat treatment was given to all tools with the only difference being the tool style.

Upon receipt of the fastener and tools, they were sample inspected to assure that they complied with the specification requirements. Of particular concern was compliance with recess and tool dimensional requirements and hardness values. The supplied hardware satisfied the specification requirements.

End Load

End load is defined as the externally imposed force by the operator acting along the longitudinal fastener/driver axis.

The end loads used for the initial failure were 1.3 lbs, 5 lbs, 10 lbs, and 20 lbs. There was some interest in testing at zero end load since some of the recesses to be tested were designed to be end load independent. However, the 1.3 lbs end load was the lowest repeatable with the test equipment.

A 20 lb end load was chosen as the maximum end load for the first failure. Preliminary laboratory tests showed that for those recesses sensitive to end load, the greatest rate of change of torque capability vs end load occurred in the low range (less than 10 lbs). Also, the preliminary tests indicated that the increase in torque capability with the higher end loads (above 20 lbs) was very small for the initial failure.

For the second failure, end loads of 10, 20, 40, and 60 lbs were used. This was done because of the general knowledge that end loads increased with difficulty of removal in field conditions. It was also anticipated that this range would adequately include typical practical conditions.

Paint

This condition was included to duplicate field conditions of paint in the recess.

Prior to painting, the test screws were cleaned with methyl ethyl ketone (MEK) and dried. The screws were pressed into thick cardboard (faces flush with the cardboard) and the heads (and cardboard) painted

with MIL-P-23377 primer. The primer thickness was measured by placing pieces of precision steel foil at various places on the board and measuring the primer build up with a micrometer. The primer thickness varied from .7 to .9 mills. Two coats of polyurethane paint (MIL-C-83286) were then applied which measured between 2 to 2.5 mills thickness for a total primer and paint thickness of 2.7-3.5 mills. This is the same paint and application procedures as used on current Air Force systems.

Off Angle

The "off angle" or "off-set angle" refers to the angular offset or misalignment between the axis of the screw and the axis of the bit. This was also included to duplicate actual field conditions. Again from experience, it was known that perfect alignment is difficult to attain or maintain in many cases and sometimes impossible to attain due to space or geometry constraints. Zero and seven degrees were the chosen values for the test. These values were considered practical extremes. This was substantiated by the field data survey described in Section V. As the fastener did not rotate, the test conditions do not duplicate the coning action found to exist from the field data.

Soft and Hard Bits

The performance of a recess fastener-bit system can be affected by the bit hardness. Experience has favored making the bits harder rather than softer. There is no known data that quantifies recess performance with bit hardness. In order to fully understand the effects of bit hardness relative to the fastener, tests were made with two bit hardness values. The "hard" bits were at 60-62 Rockwell "C" hardness. This value is at the high end of present bit hardness requirements. In order to be sure of seeing the effect of hardness, the "soft" bits were procured with a 45-48 Rockwell "C" hardness.

Undersized Bits

The use of undersized bits was another attempt to duplicate field conditions in this program. One of the facts of life in the field is that if a tool other than the matching tool "fits" into a recess, somebody will use it. Judging from field observations, this happens frequently (and many times not accidently). This tool misuse was duplicated in this program. A #1 Phillips bit was used instead of a #2; a #8 Torq-Set bit was used in place of a #10; etc. "Cross utilization (a Phillips bit in a Torq-Set recess, etc.) was not duplicated even though this also occurs in the field.

Worn Bits

It was suspected at the start of the program that the use of worn bits had to have significant impact on the maximum obtainable torque. Some examples of laboratory tests run with worn bits collected in the field are discussed below.

Two "heavily" worn (bit edges severely rounded) #3 Hi-Torque bits were tested with a new #10 tensile head screw. With 20 lb. end-load imposed, the removal torques ranged from 22 to 47 inch pounds and installation torques ranged from 59 to 79 inch pounds. A new bit would have produced an average of 93 inch pounds under the same conditions. A "slightly" worn #8 Torq-Set bit produced 82 inch pounds removal torque compared to 93 inch pounds for a new bit used on a #10 shear head screw. A "heavily" worn #2 Phillips bit used with a new #10 tensile head screw produced only 47 inch pounds of torque compared to values up to 100 inch pounds for new bits. These tests confirmed our suspicion that bit wear is an important parameter in the ability of the recess and bit to generate torque.

To achieve uniform wear, an attempt was made to wear the bits artificically. A 12 pound capacity rock tumbler was used. The tumbler was loaded with fifty 7/8 inch, six point tumbling stars (obtained from Keener Sand and Clay, Columbus OH) along with the test bits; this load was tumbled (dry) for 150 hours. Due to the size of the tumbling stars, some bits, such as Phillips and Torque Set, were not worn on the edges of the removal tangs. A Hi-Torque bit was well worn. The question of equity in wear between the styles and the lack of similarilty to field wear argued against presenting the data.

Such terms as "heavy wear", "slight wear", and "obvious wear" are not very descriptive or concrete. Classifying or simulating wear did prove to be a problem in this program and was not solved to the satisfaction of the author. When worn bits obtained in the field were examined, it was decided that it would be next to impossible to obtain uniformly worn bits from the field for the test program. The bits were not readily available in sufficient quantities, were of different designs, different manufacturers, and different materials. Even if it would be possible to grade worn bits of the same type, it would be extremely difficult to relate that wear to the wear on another type of bit. Also, if the worn bit test was ever to become part of a standard test, it would be very difficult and time consuming to obtain worn bits for future tests.

3. Test Results

The results of the test program were very enlightening. The parameter effects can be seen and their affect on performance evaluated. Also, differences in recess performance can also be seen and evaluated.

A fundamental observation of the results for every style recess is that the fit of the driver in the recess determines the torque capability. Paint, off-set angle, undersize drivers, and the first failure destroy the fit that was available with new recess and bit. The design of the recess determines how much damage it or the driver sustains. The more forgiving the design (damage tolerant), the greater the second torque levels are.

Another overall observation is that none of the designs demonstrate significant damage tolerance capabilities. Each shows substantial reductions in second torque capabilities for all parameters and combination of parameters tested.

The test results are summarized in graph form in Figures 5 through 68. Each point shown is the average torque value for the fasteners tested at the particular conditions. Recall that the results for the worn drivers will not be presented. The test data is given in the appendix.

The test results for the following test parameters are briefly discussed:

a. End Load

b. Paint

c. Off-Angle

d. Soft Bits

e. Undersize Bits

f. Worn Bits

g. Torque

h. Recess Style

i. Recess Damage

j. Stock Bit and Screw Comparison

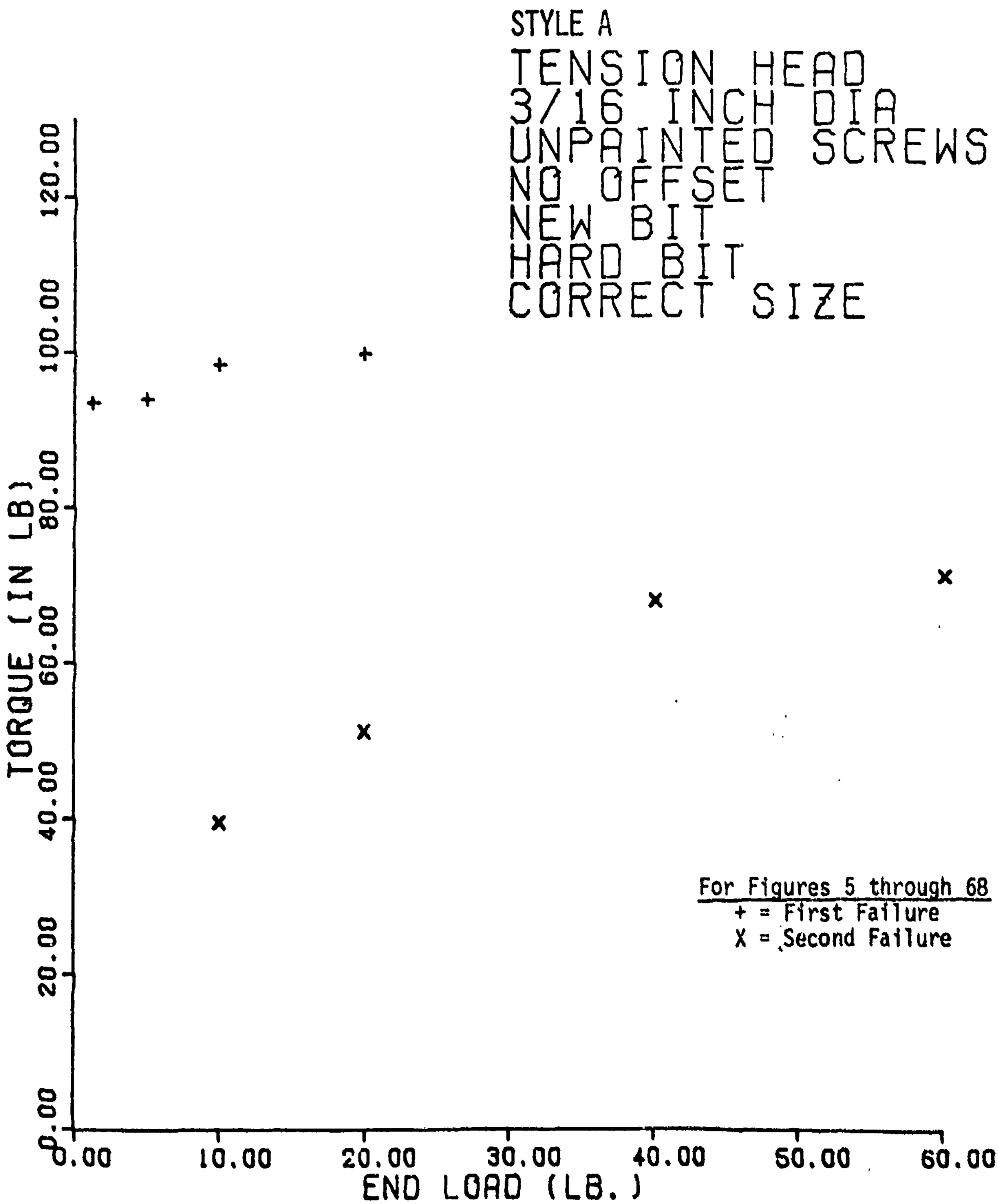


Figure 5. Style A Test Results

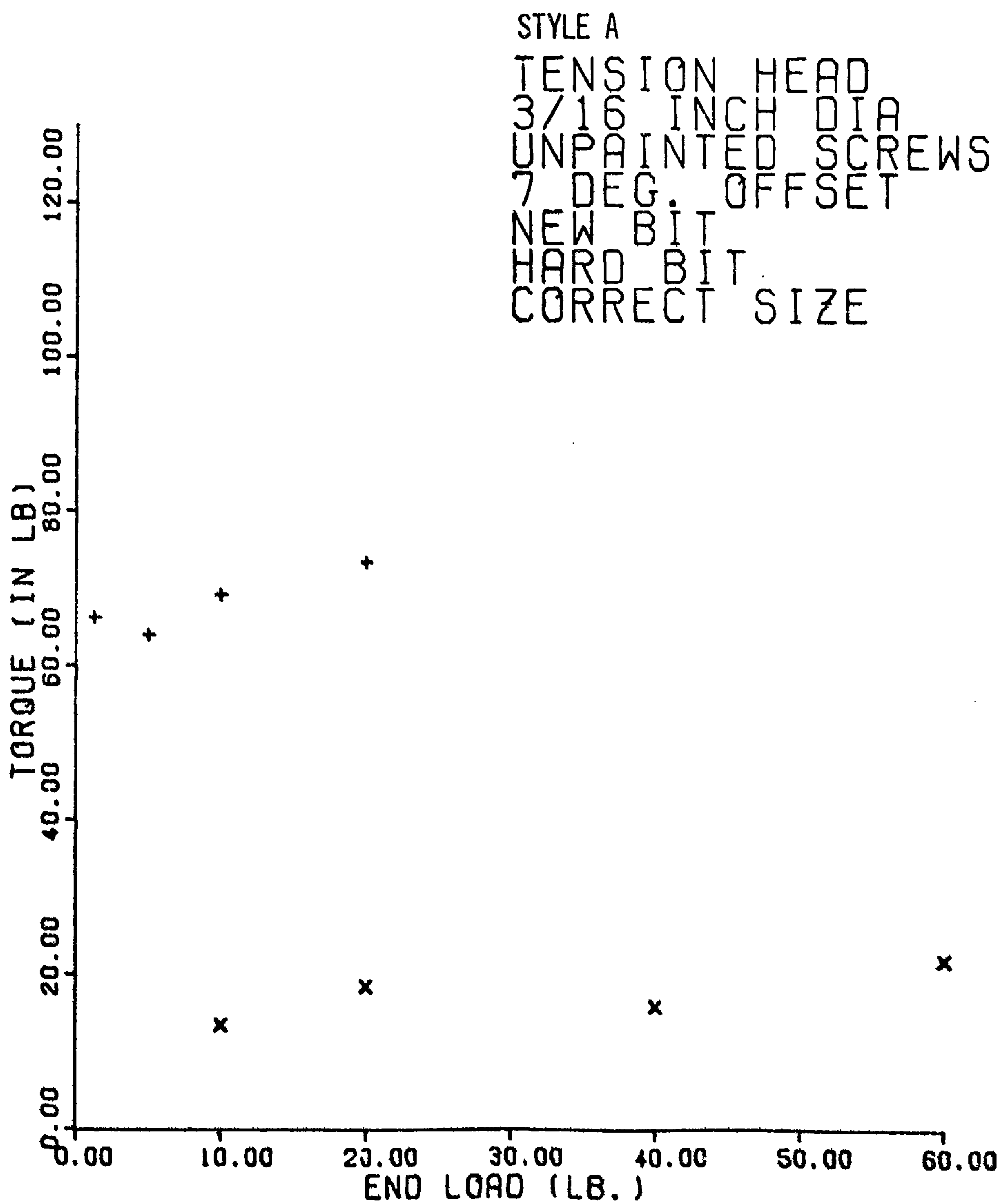


Figure 6. Style A Tests Results

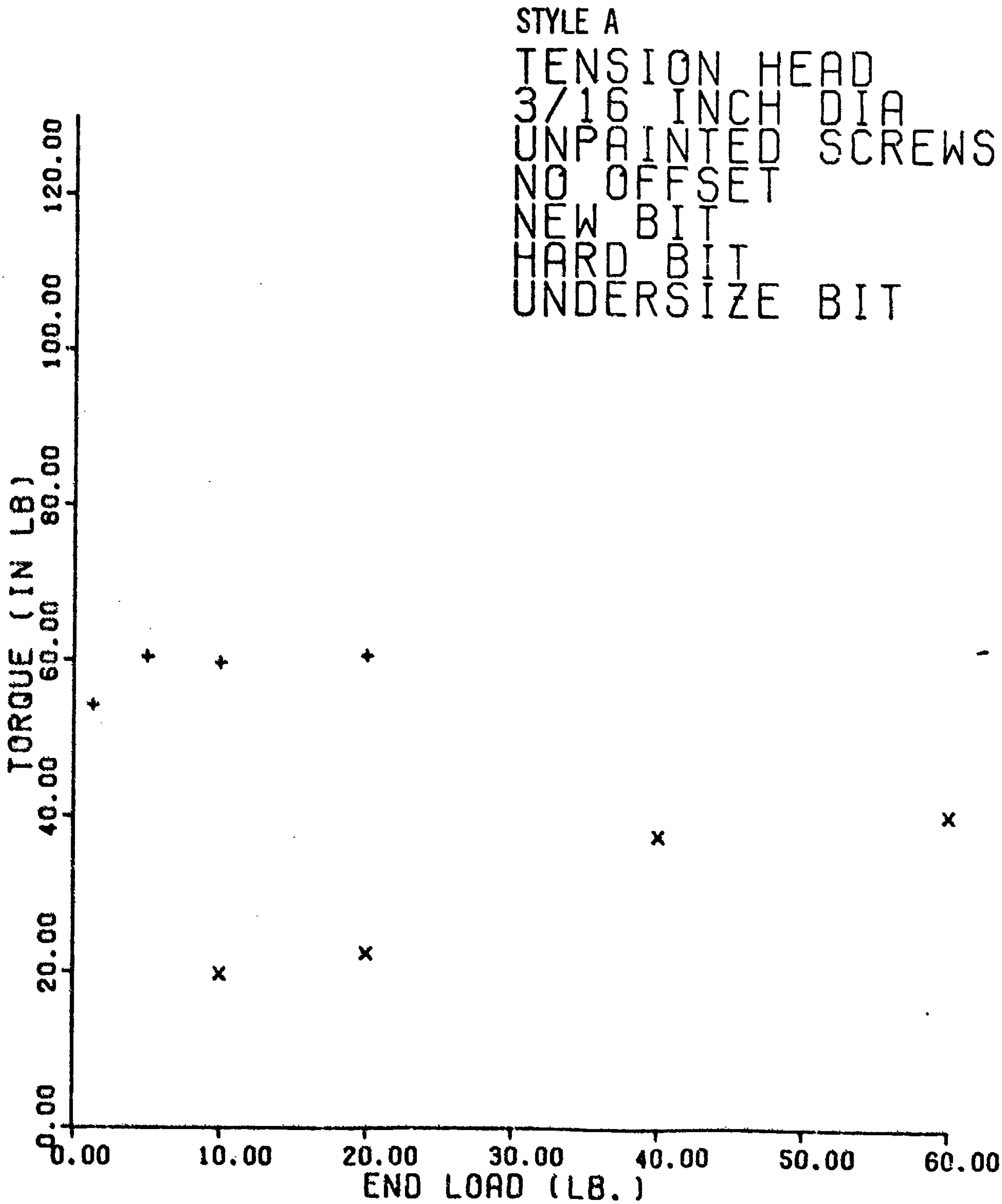


Figure 7. Style A Tests Results

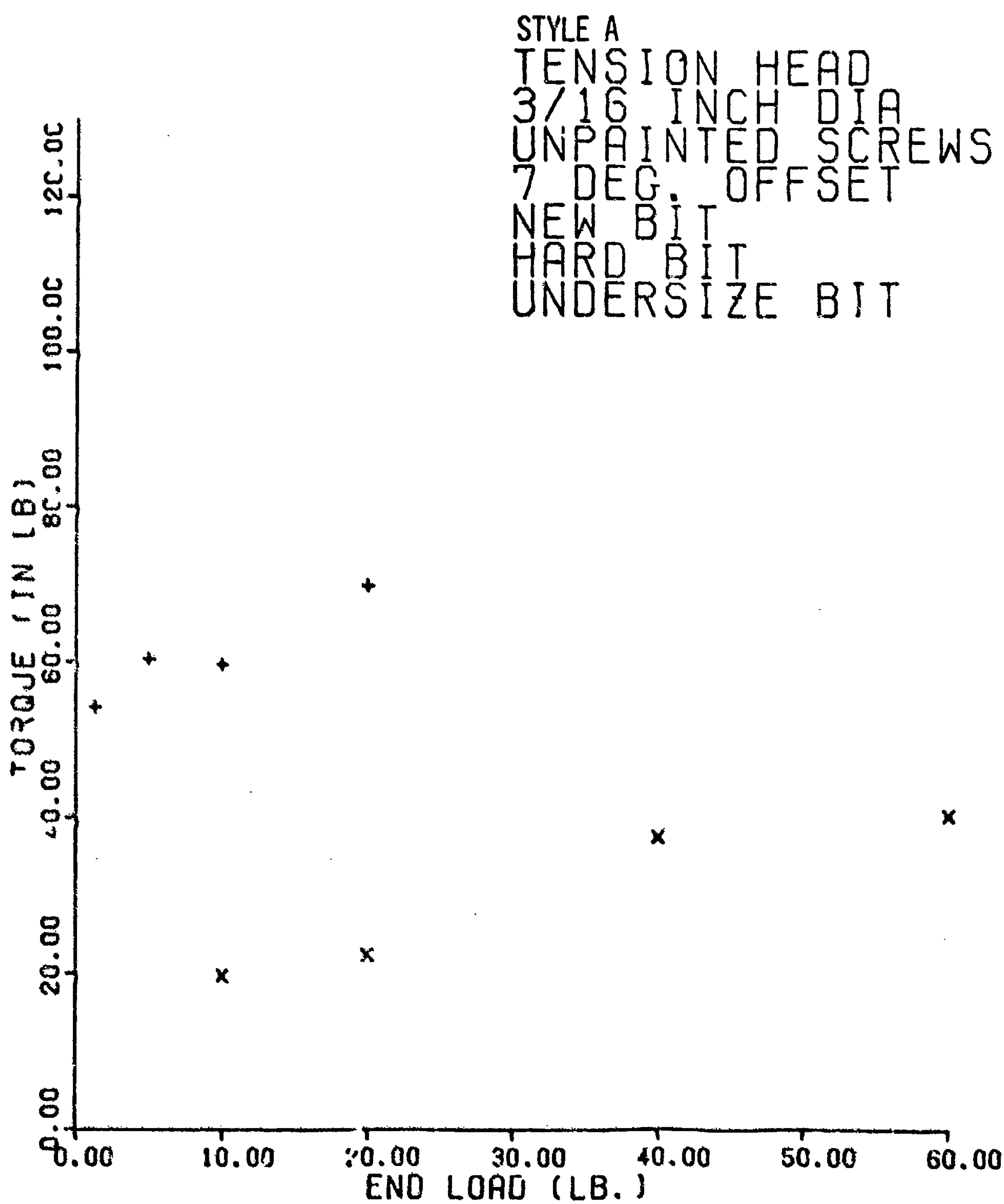


Figure 8. Style A Test Results

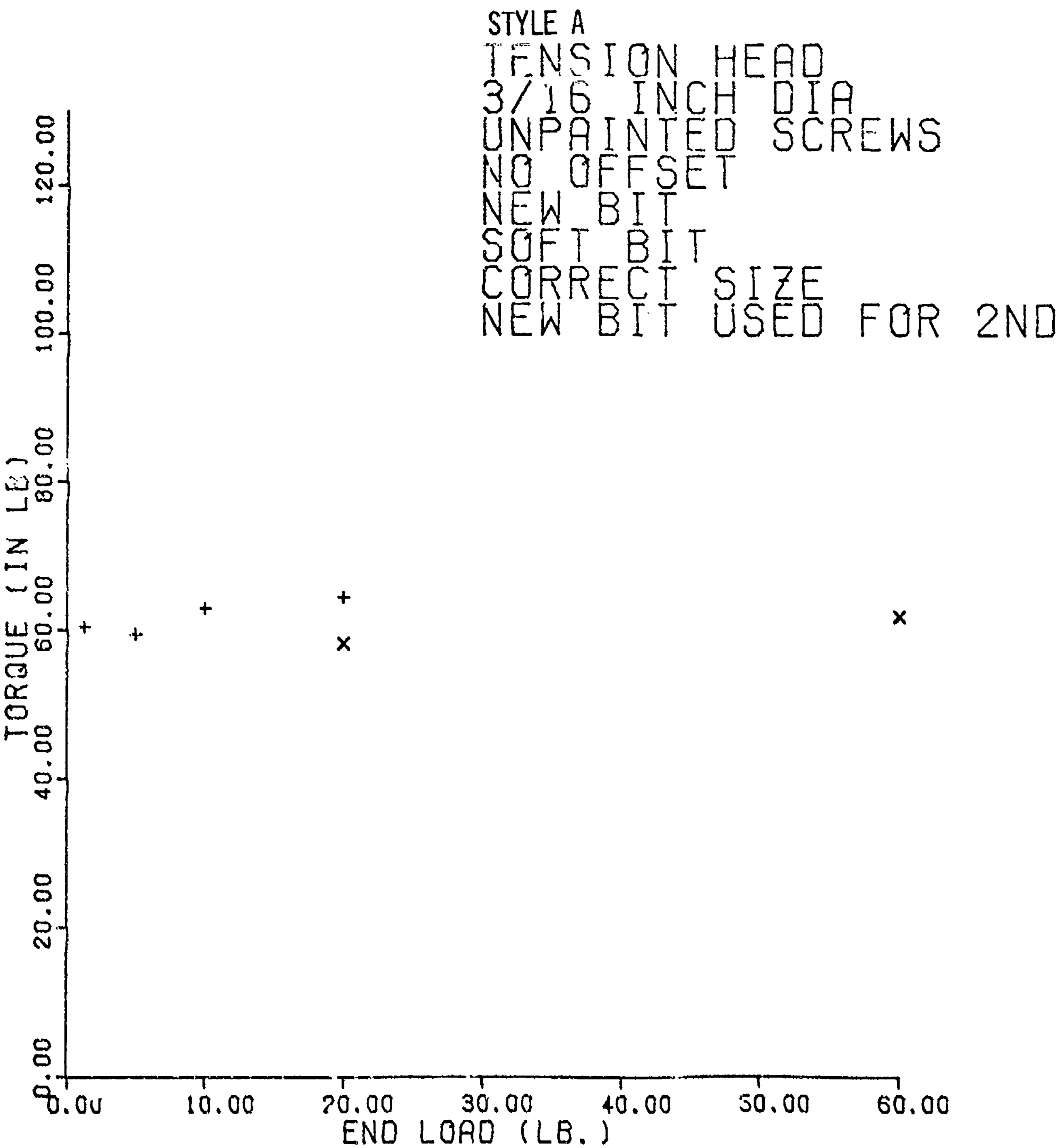


Figure 9. Style A Test Results

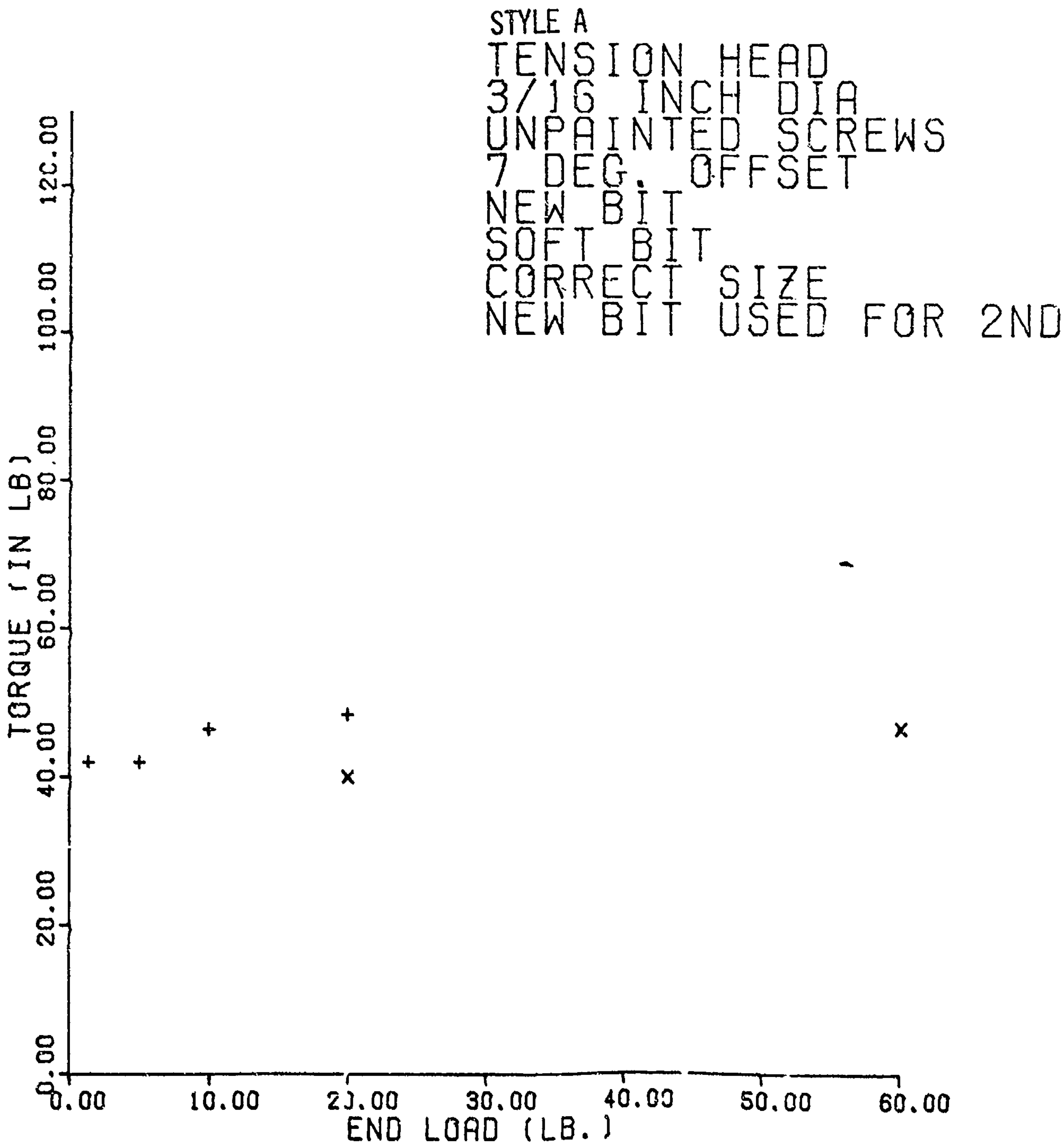


Figure 10. Style A Test Results

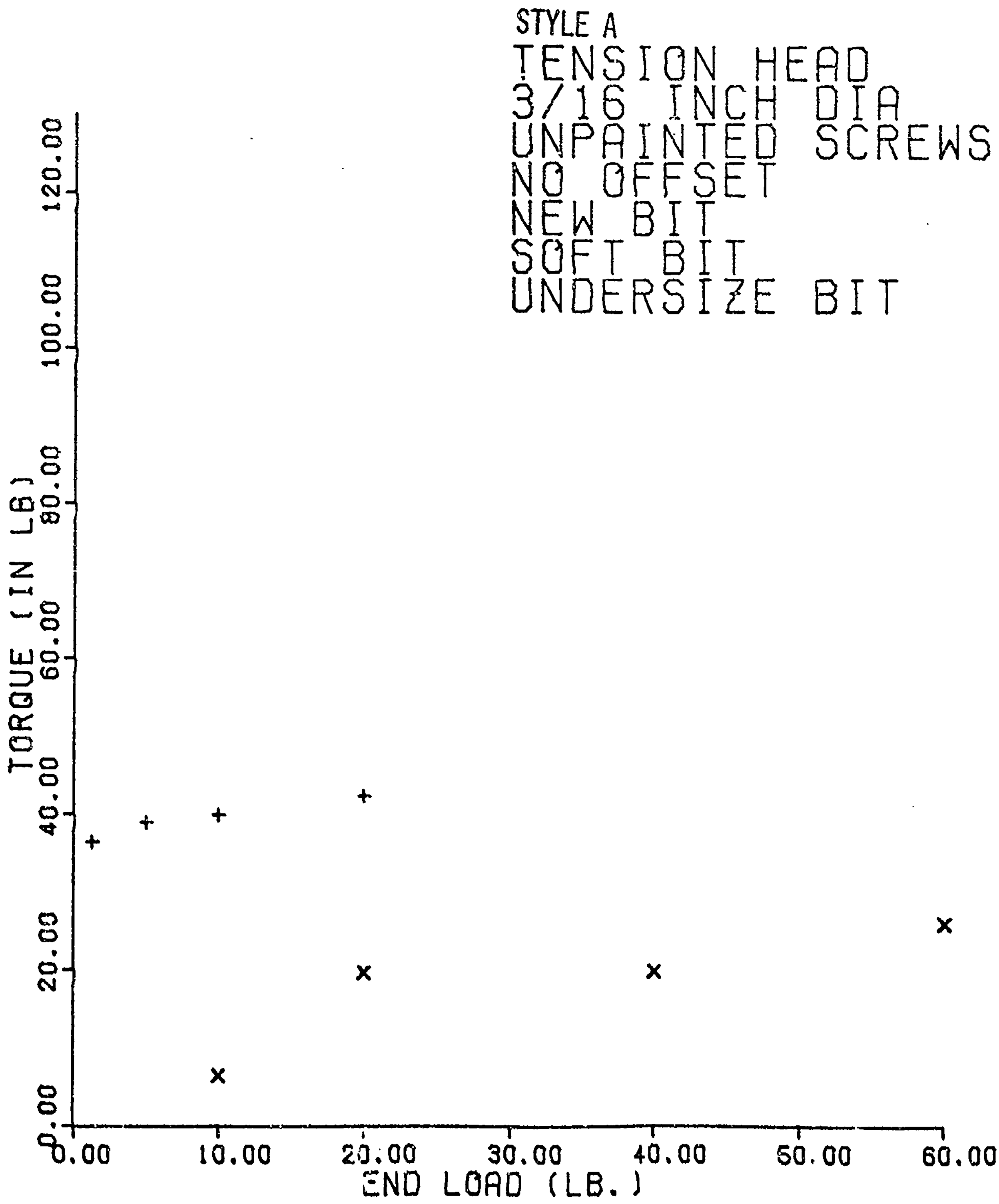


Figure 11. Style A Test Results

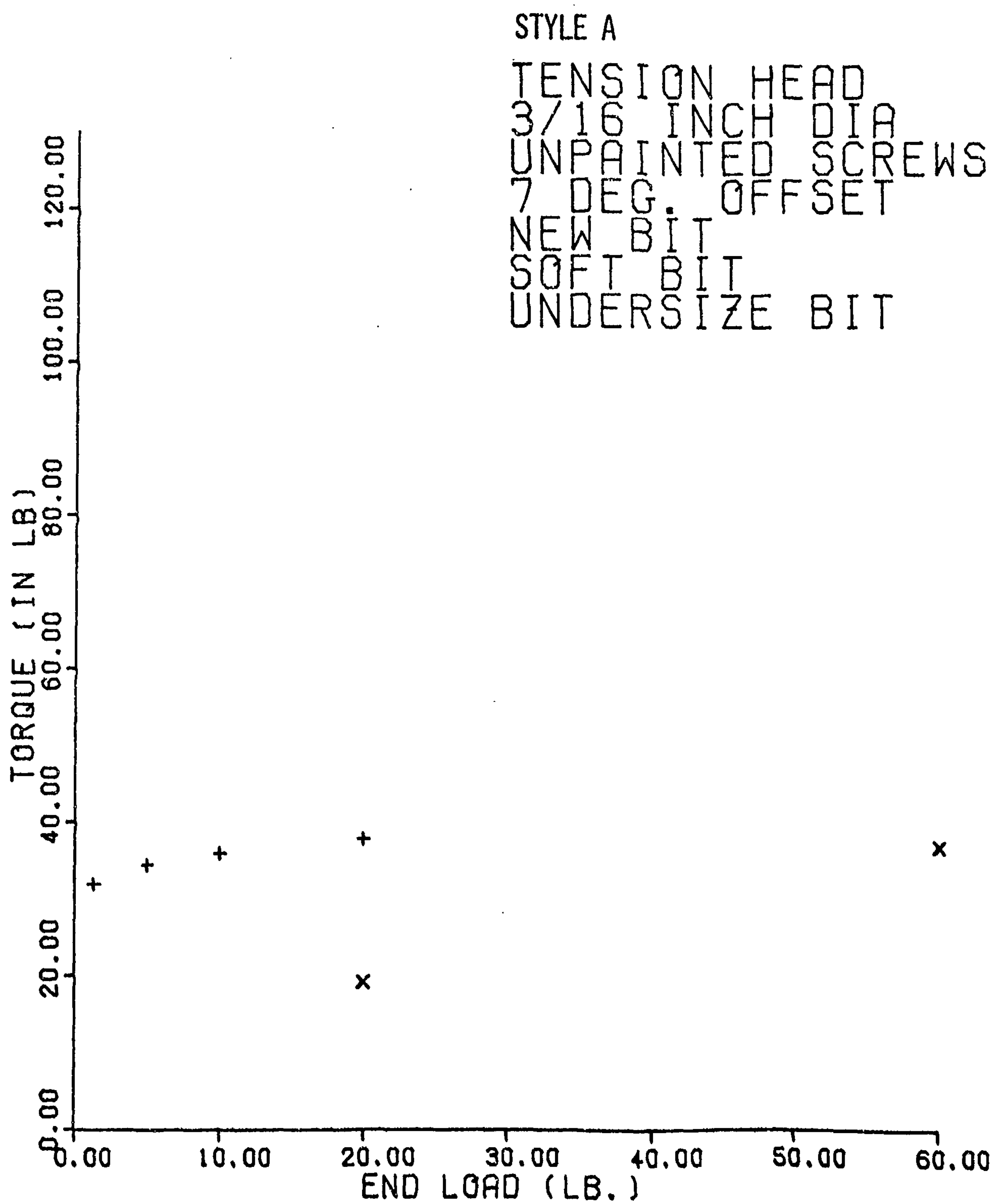
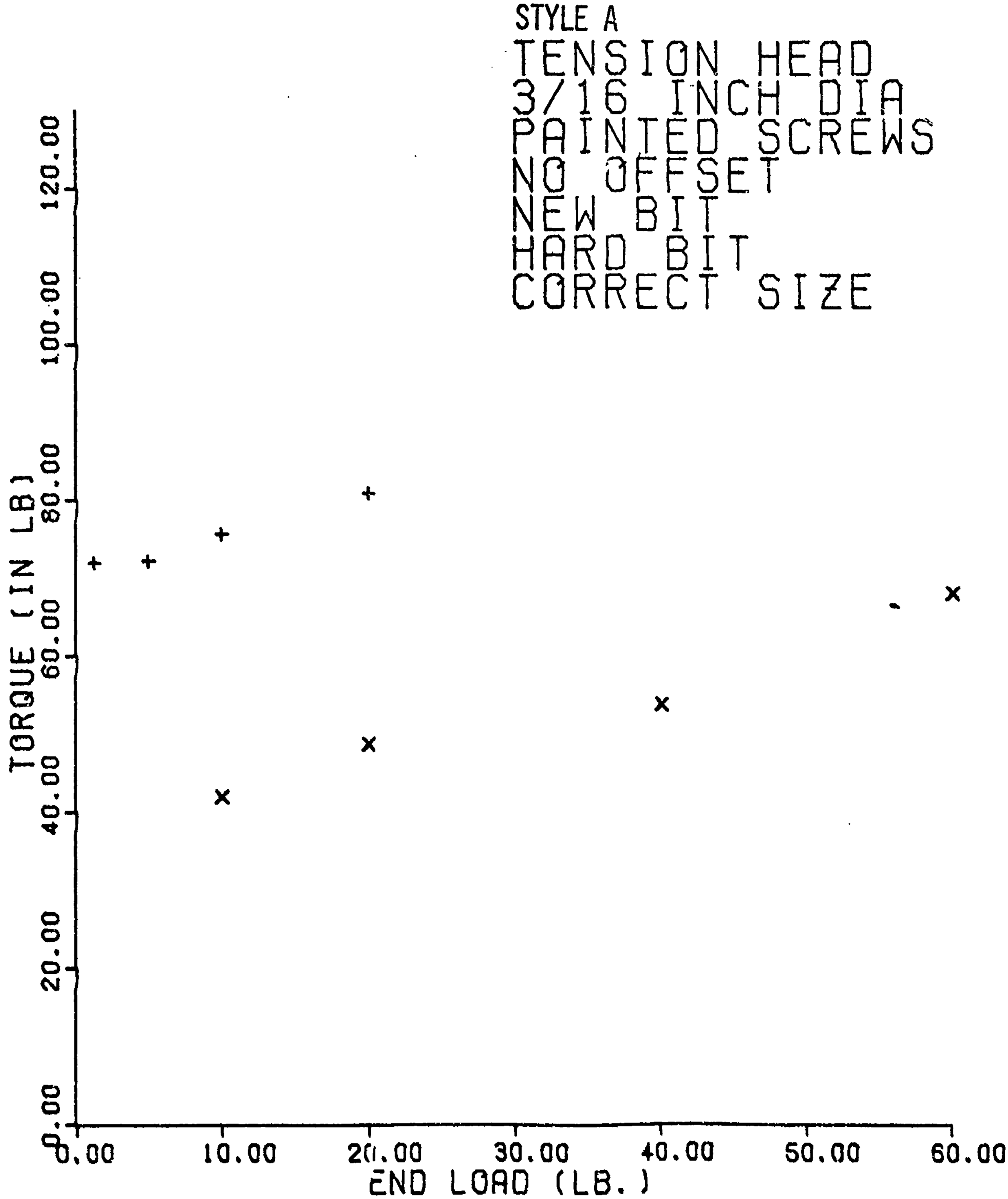


Figure 12. Style A Test Results



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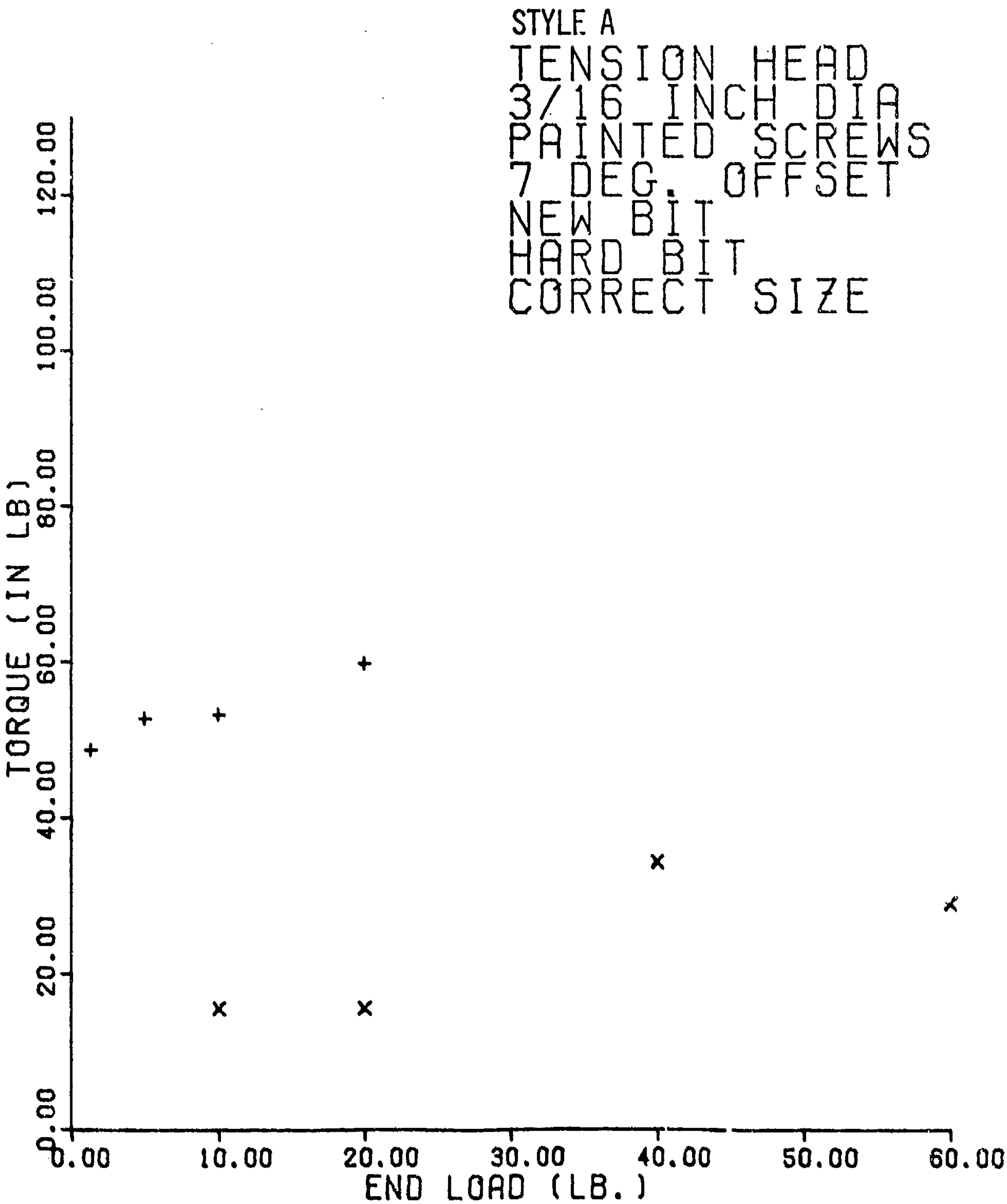

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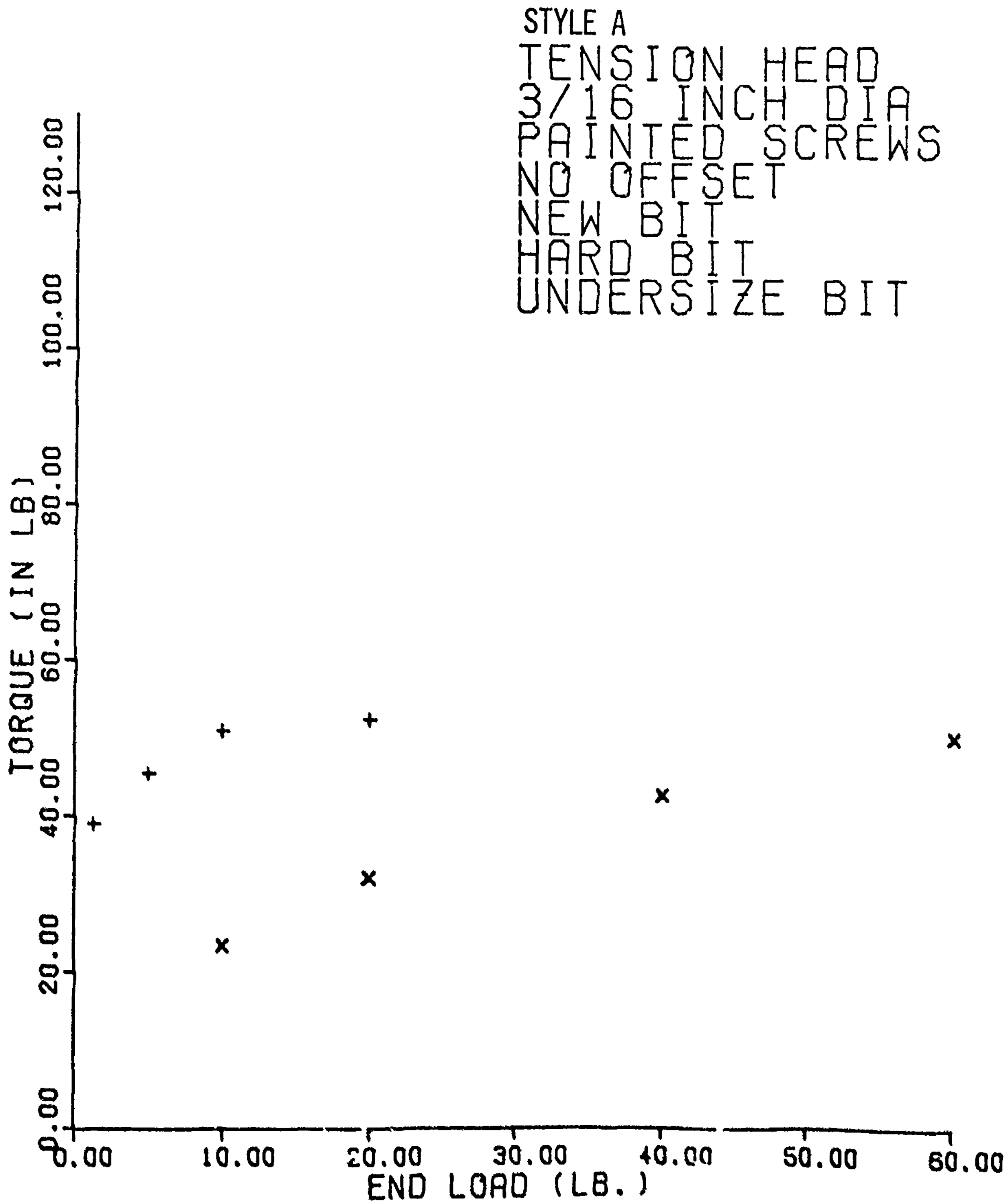

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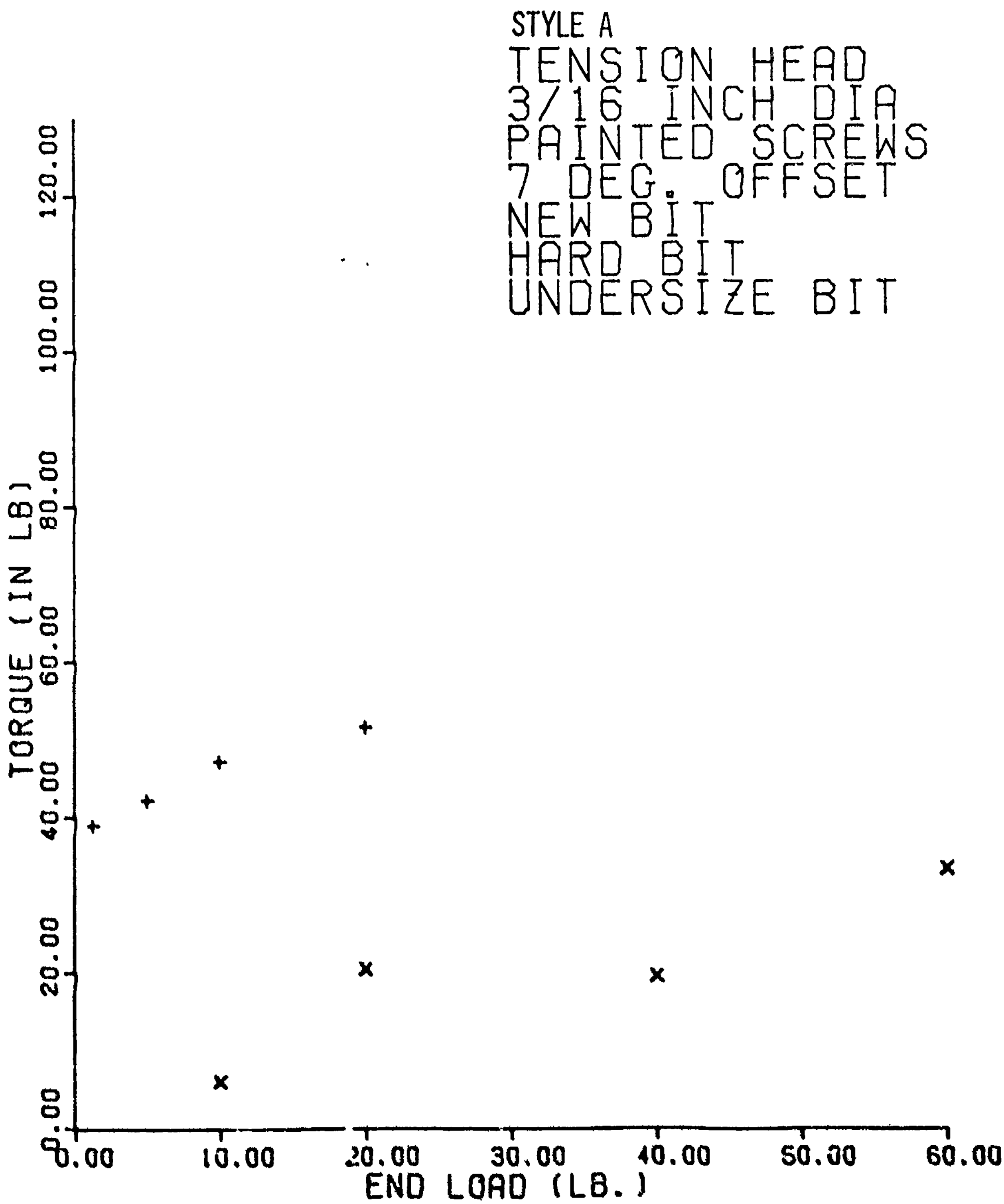

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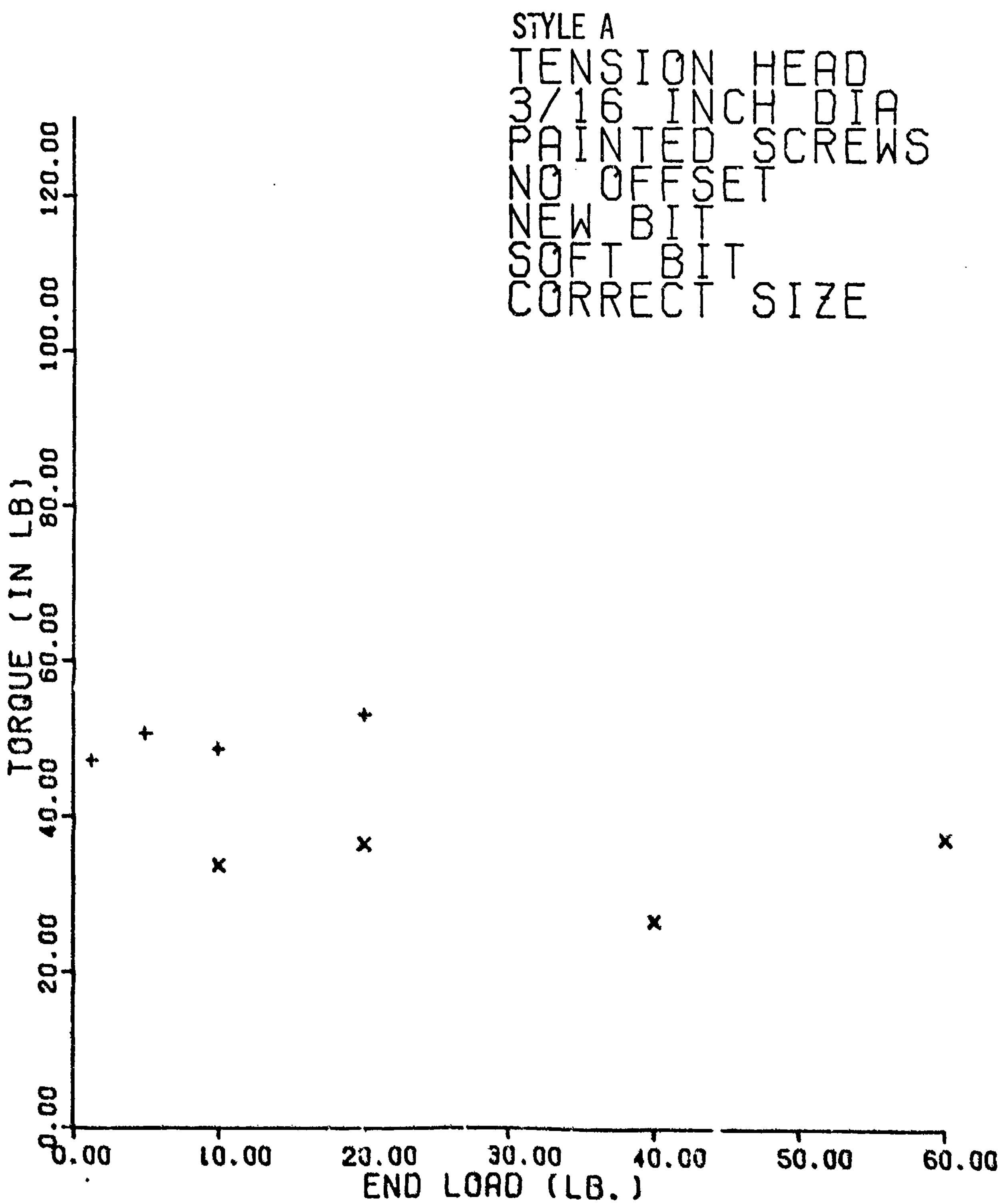

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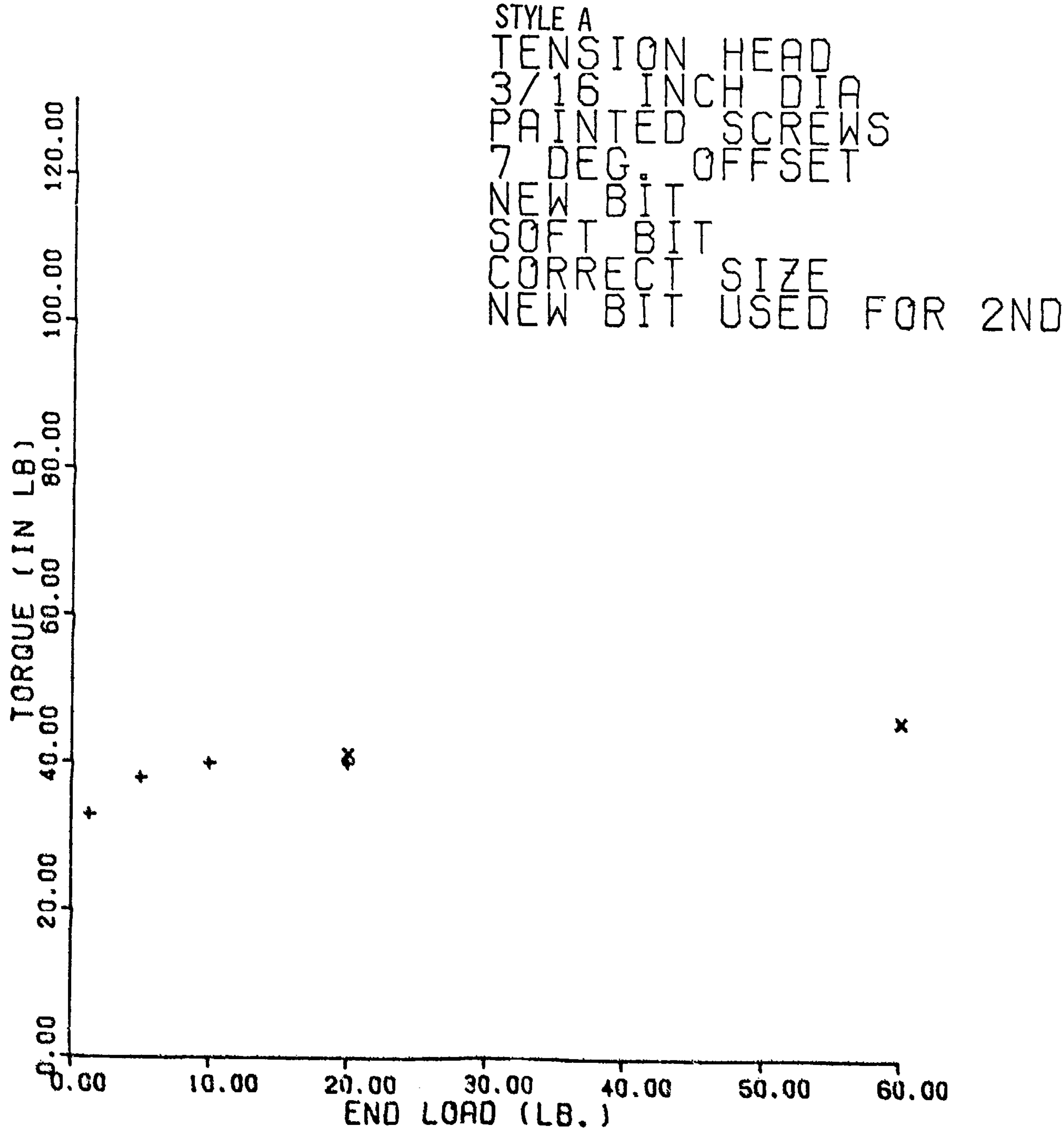

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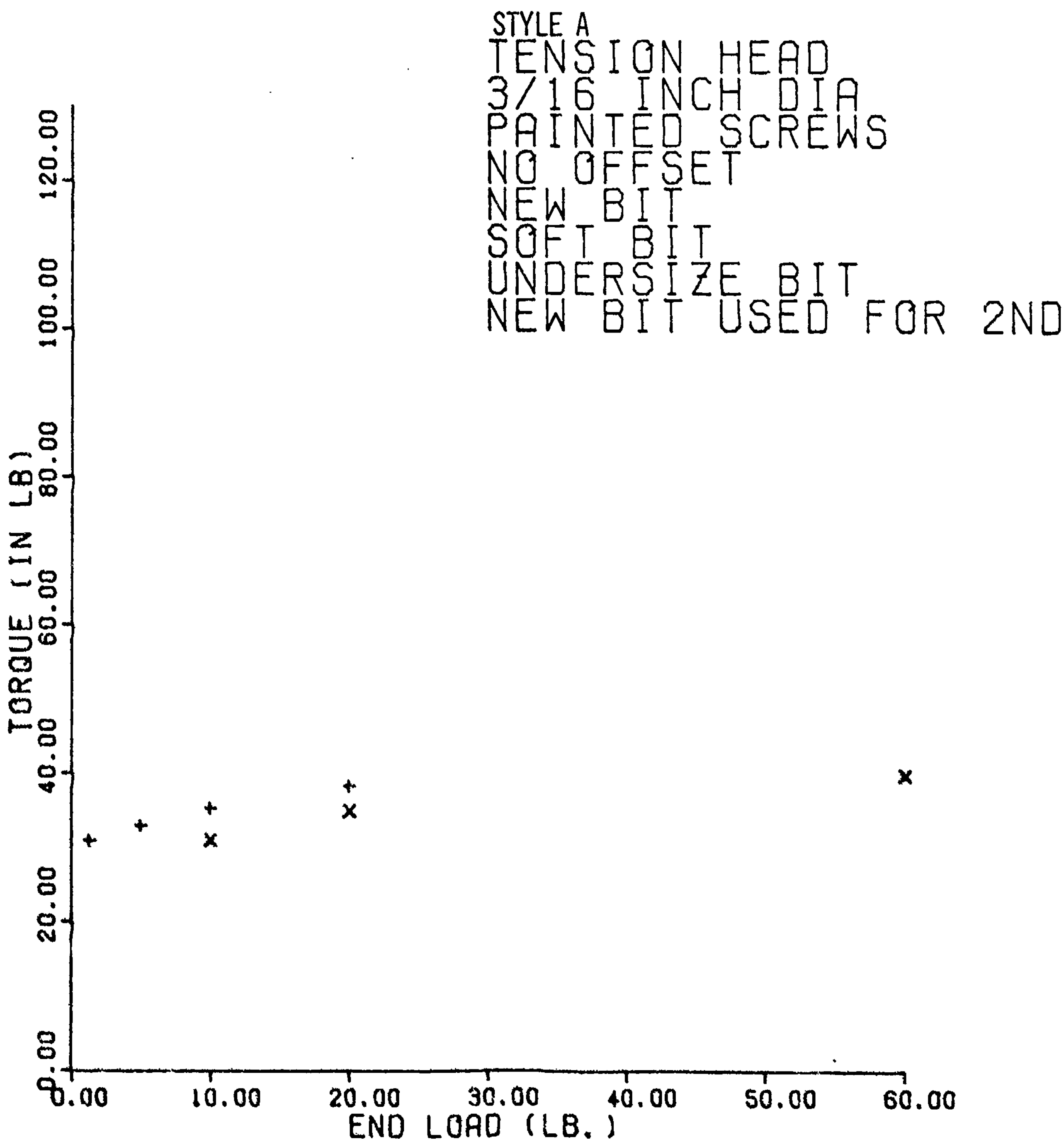

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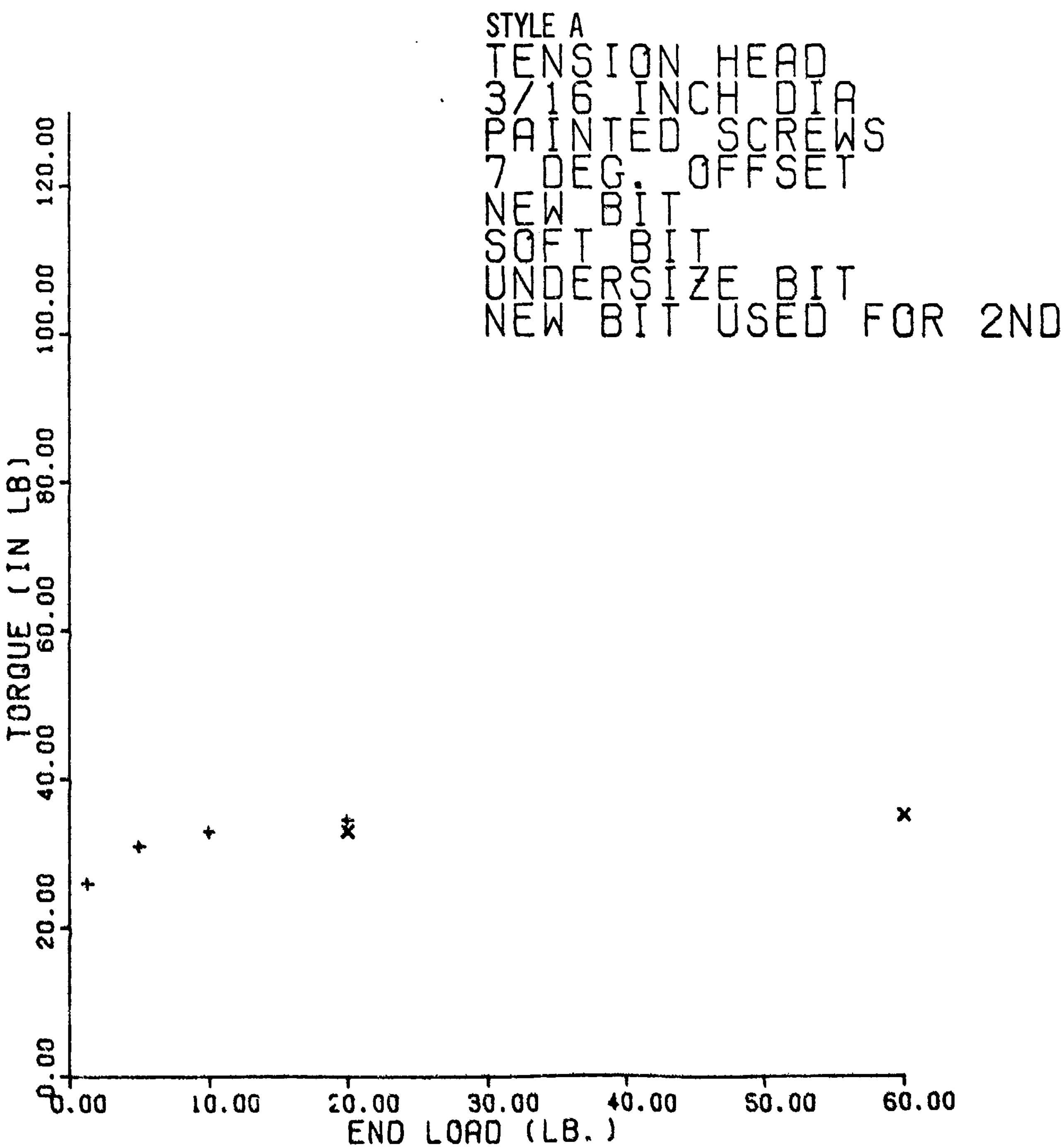

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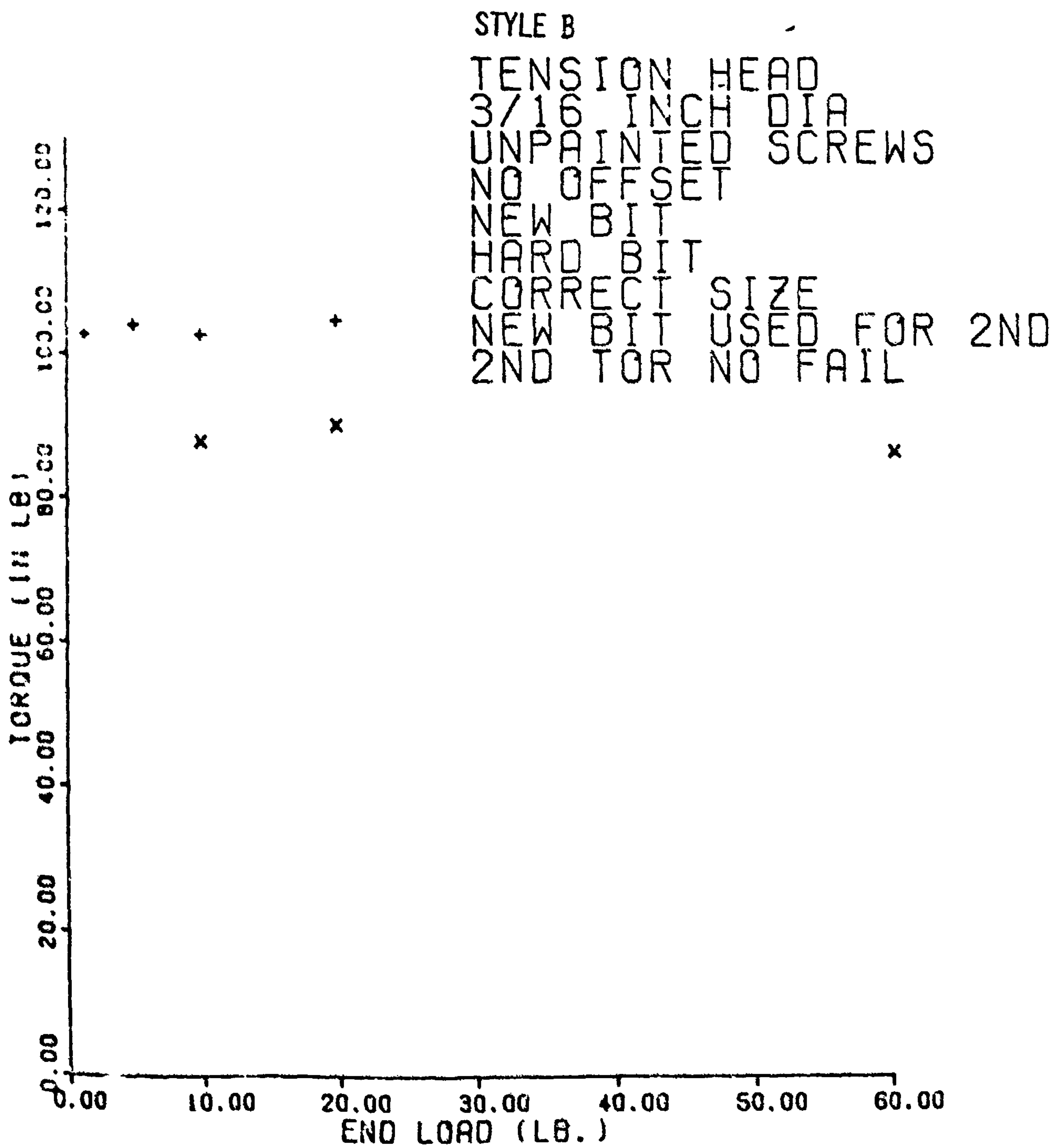

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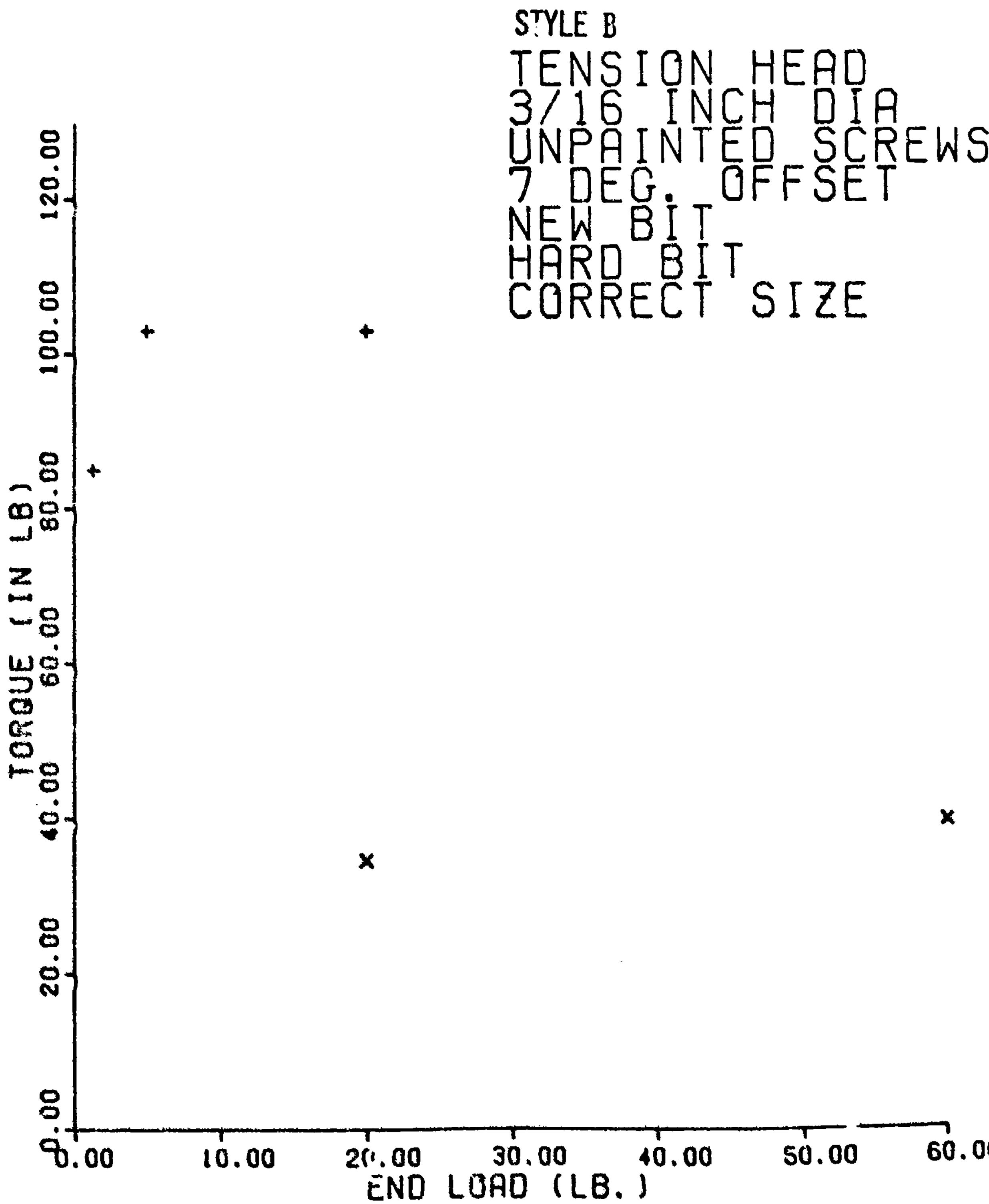

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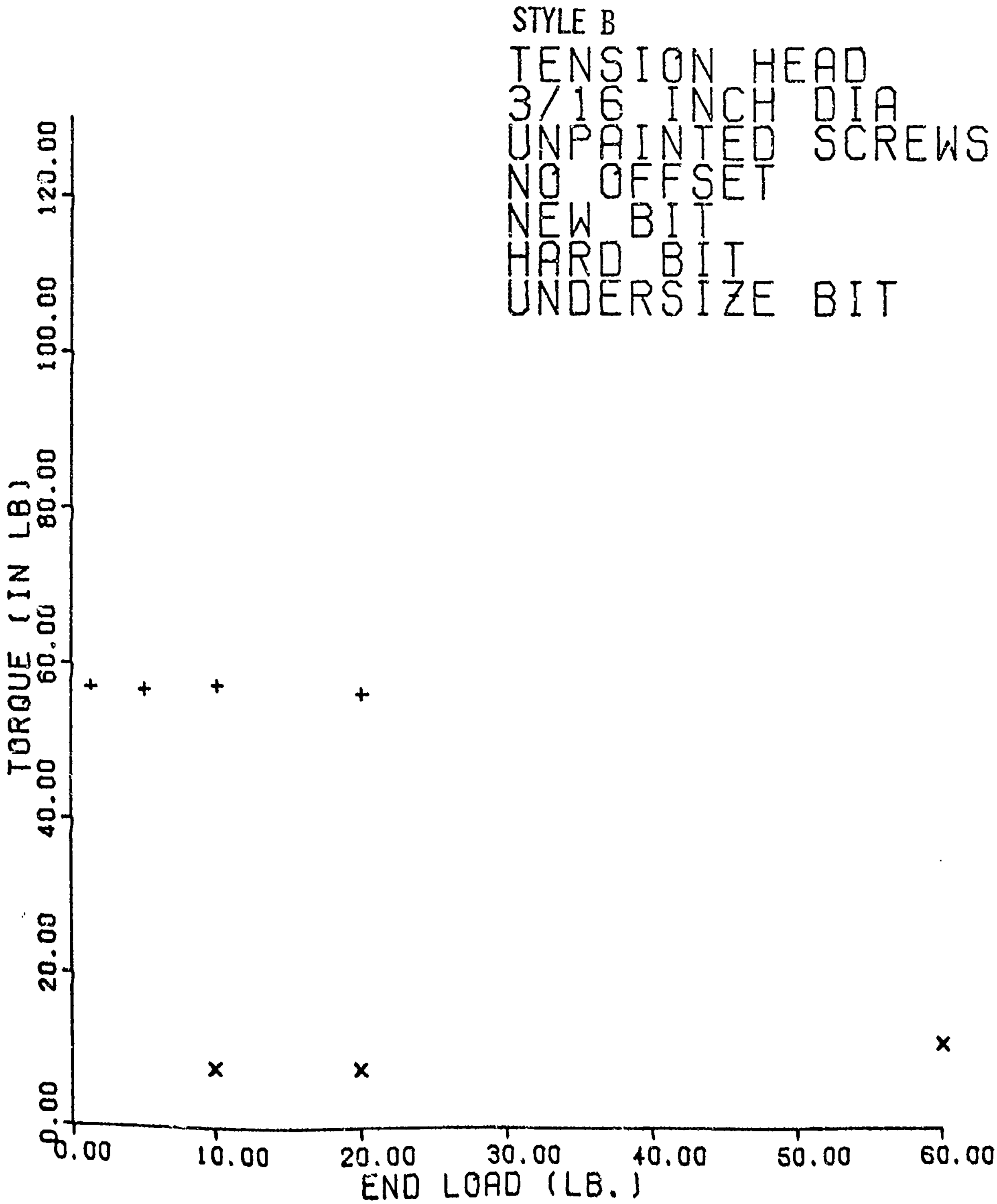

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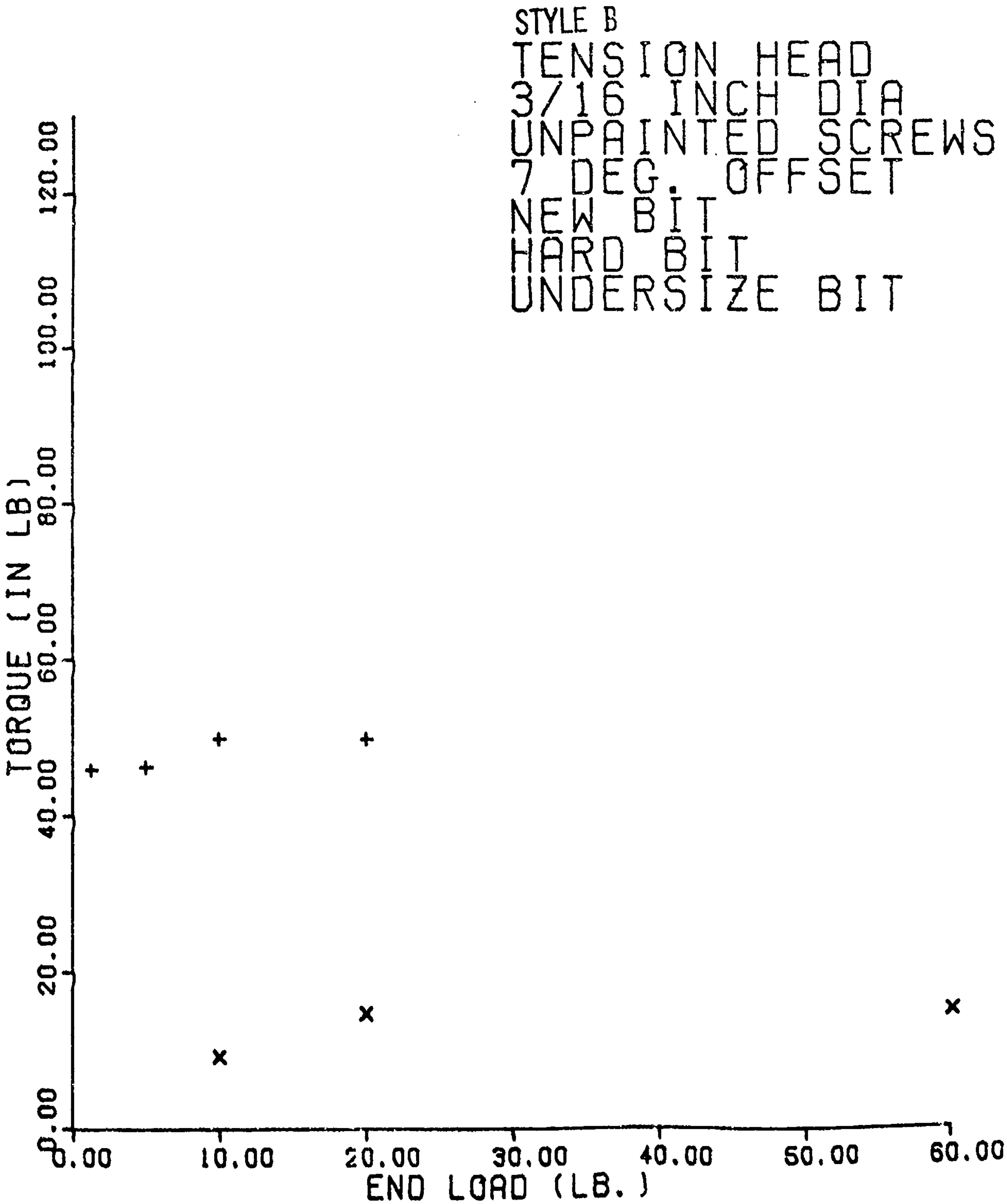

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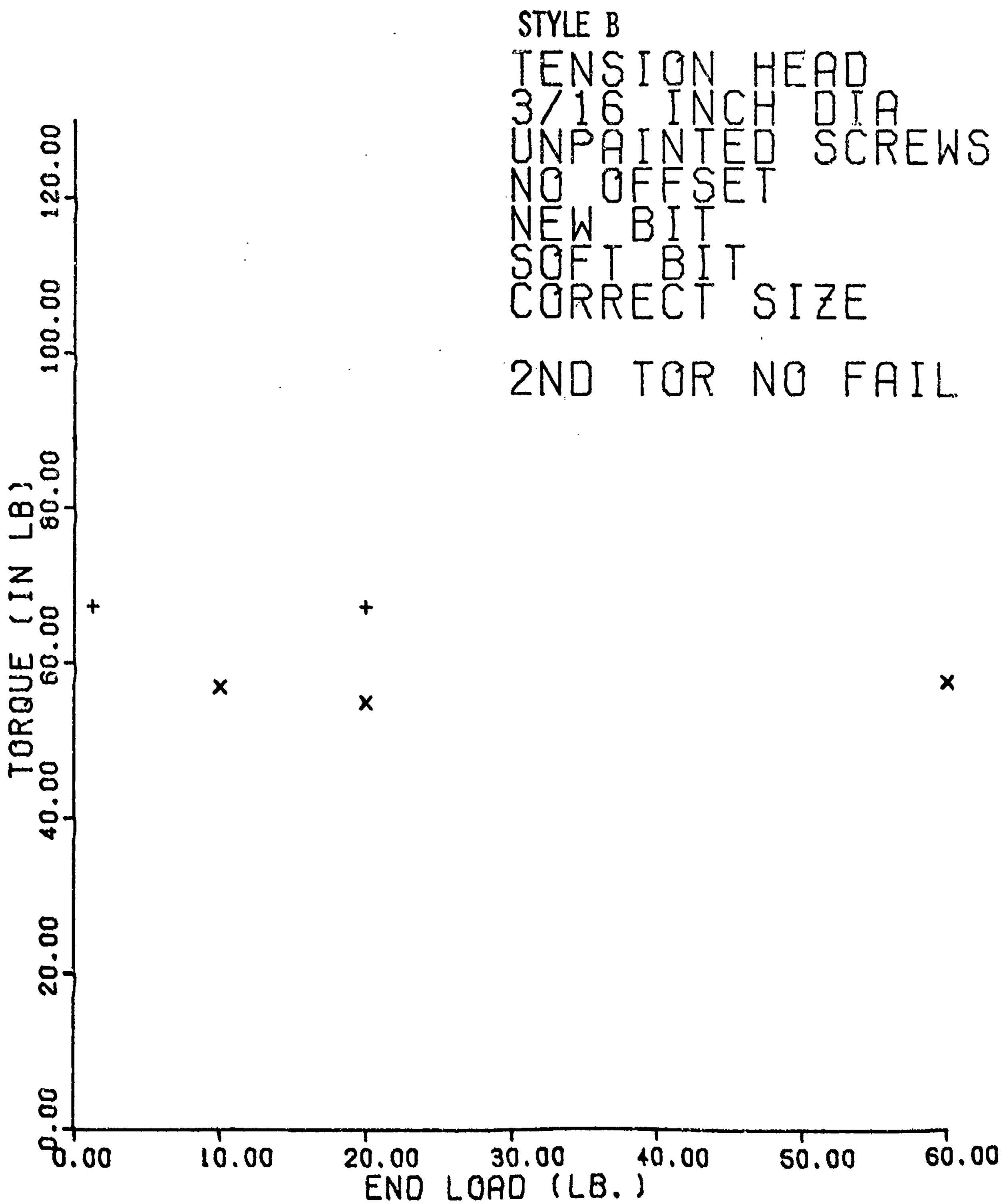

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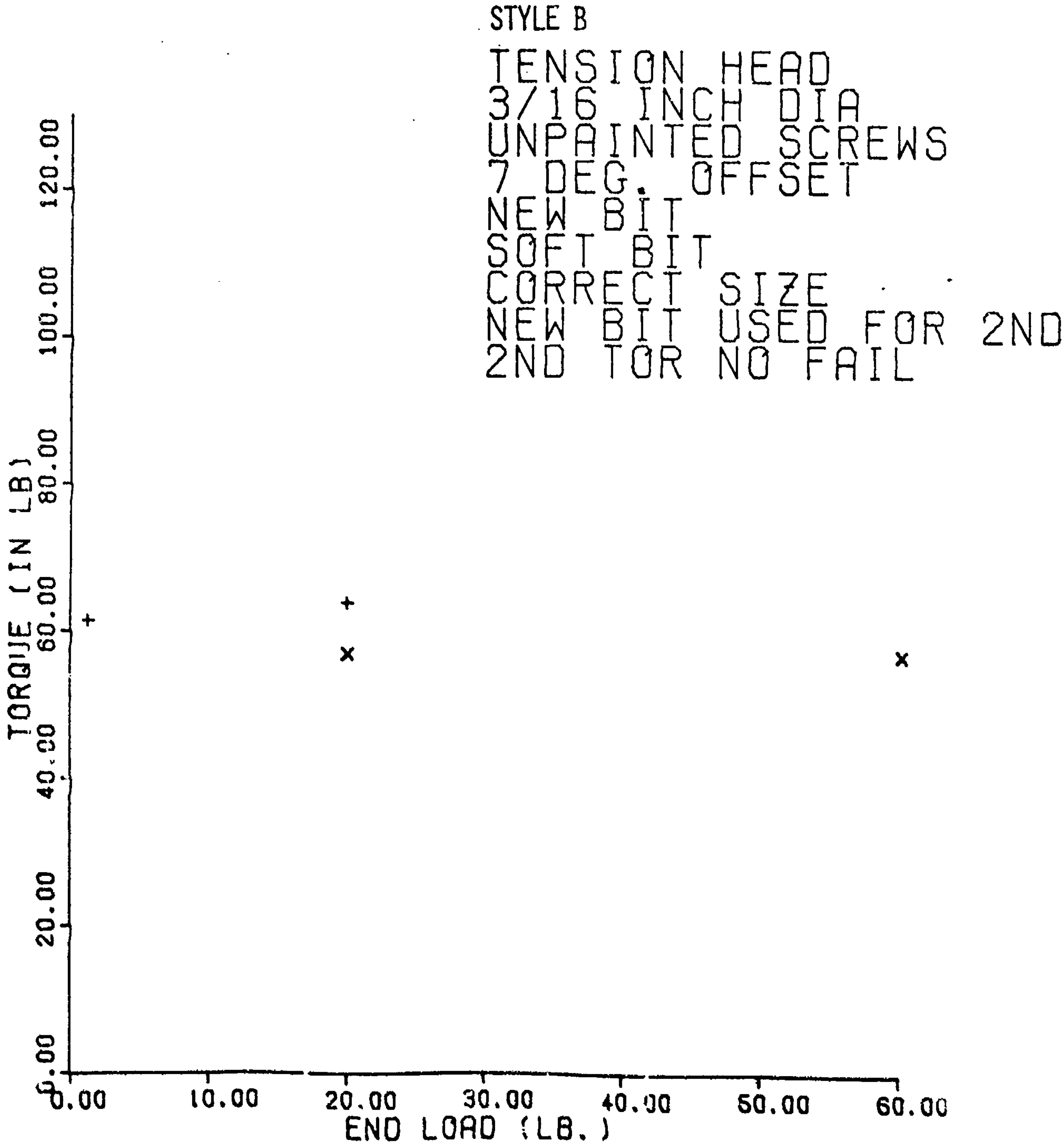

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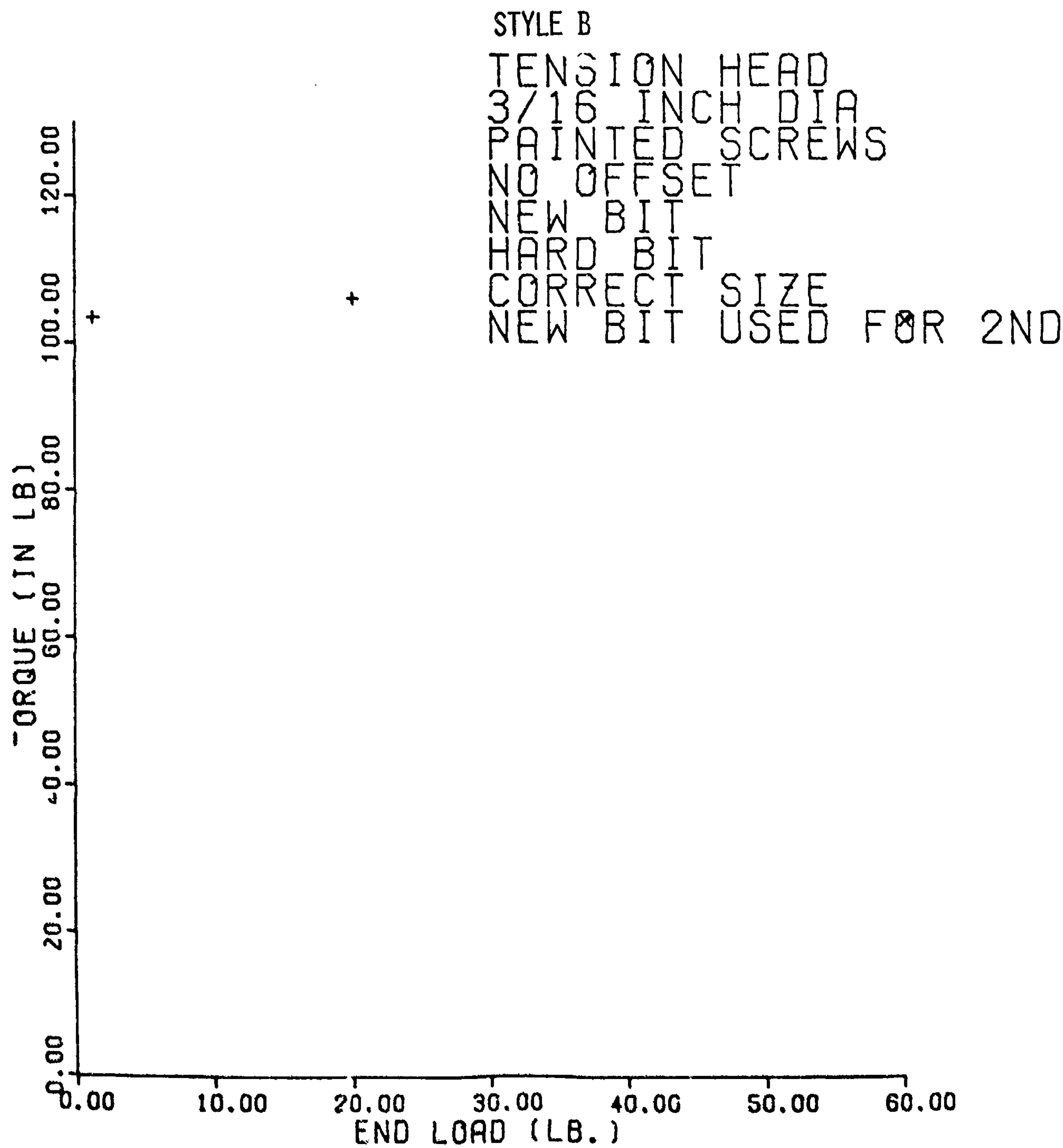

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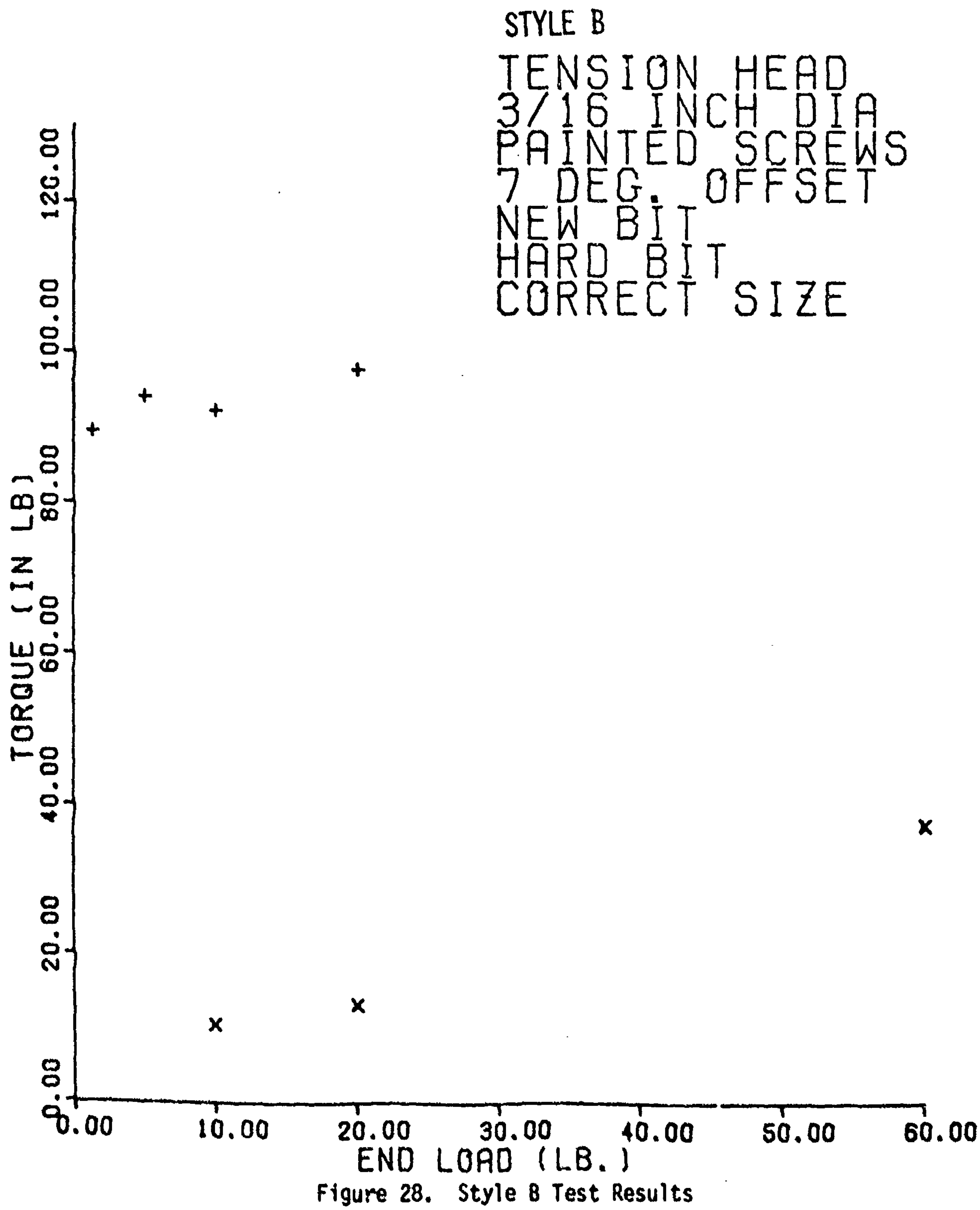

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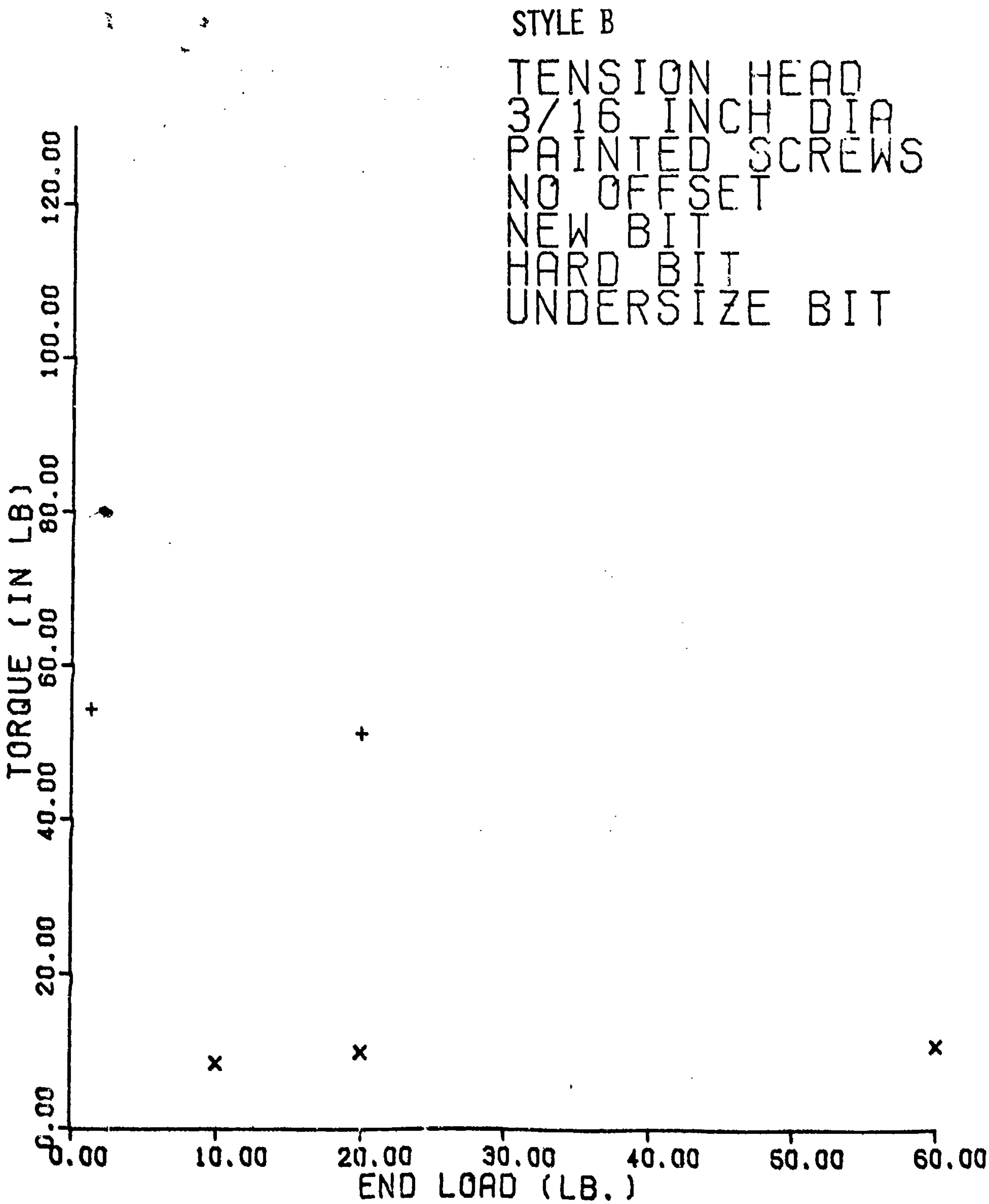

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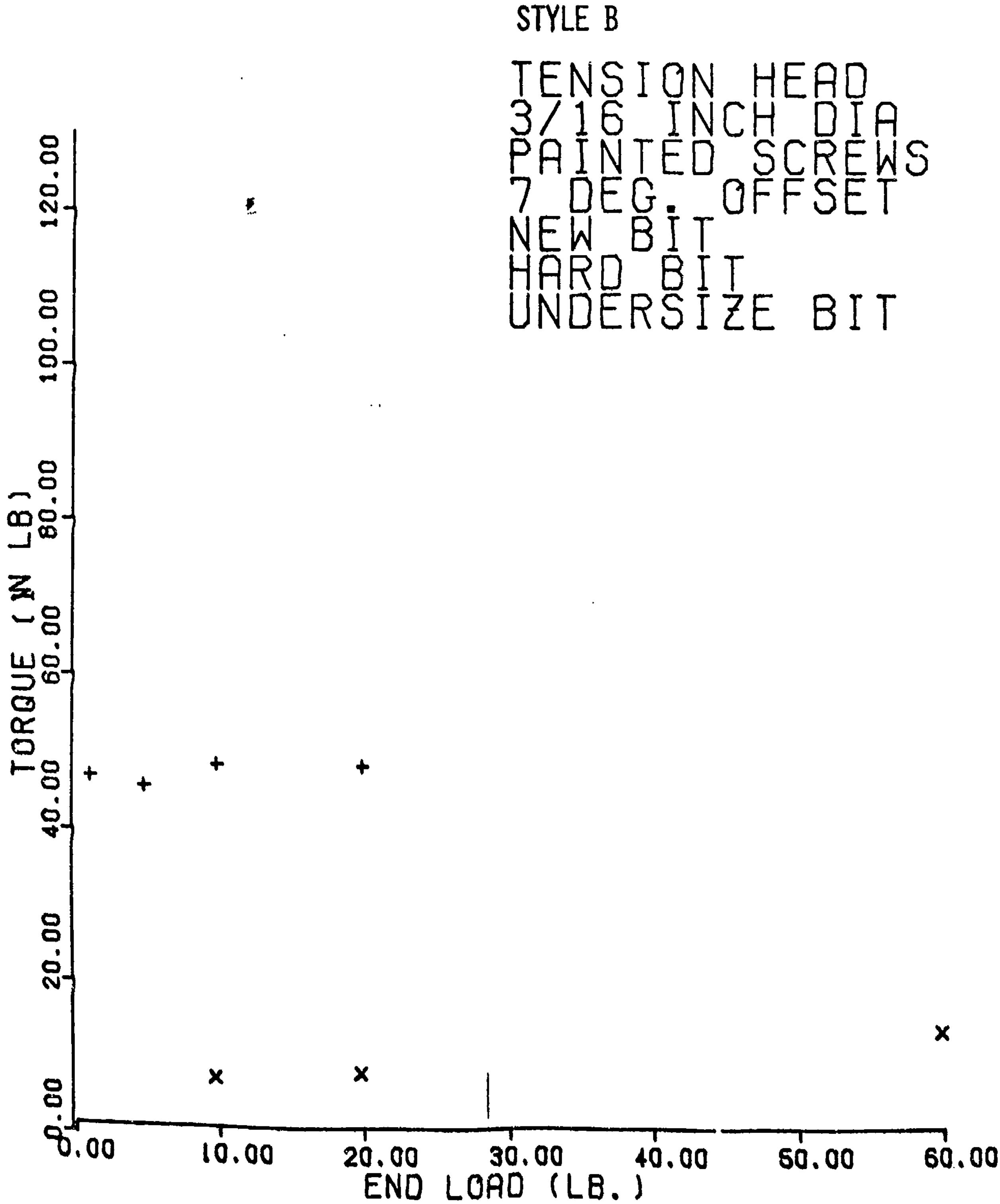

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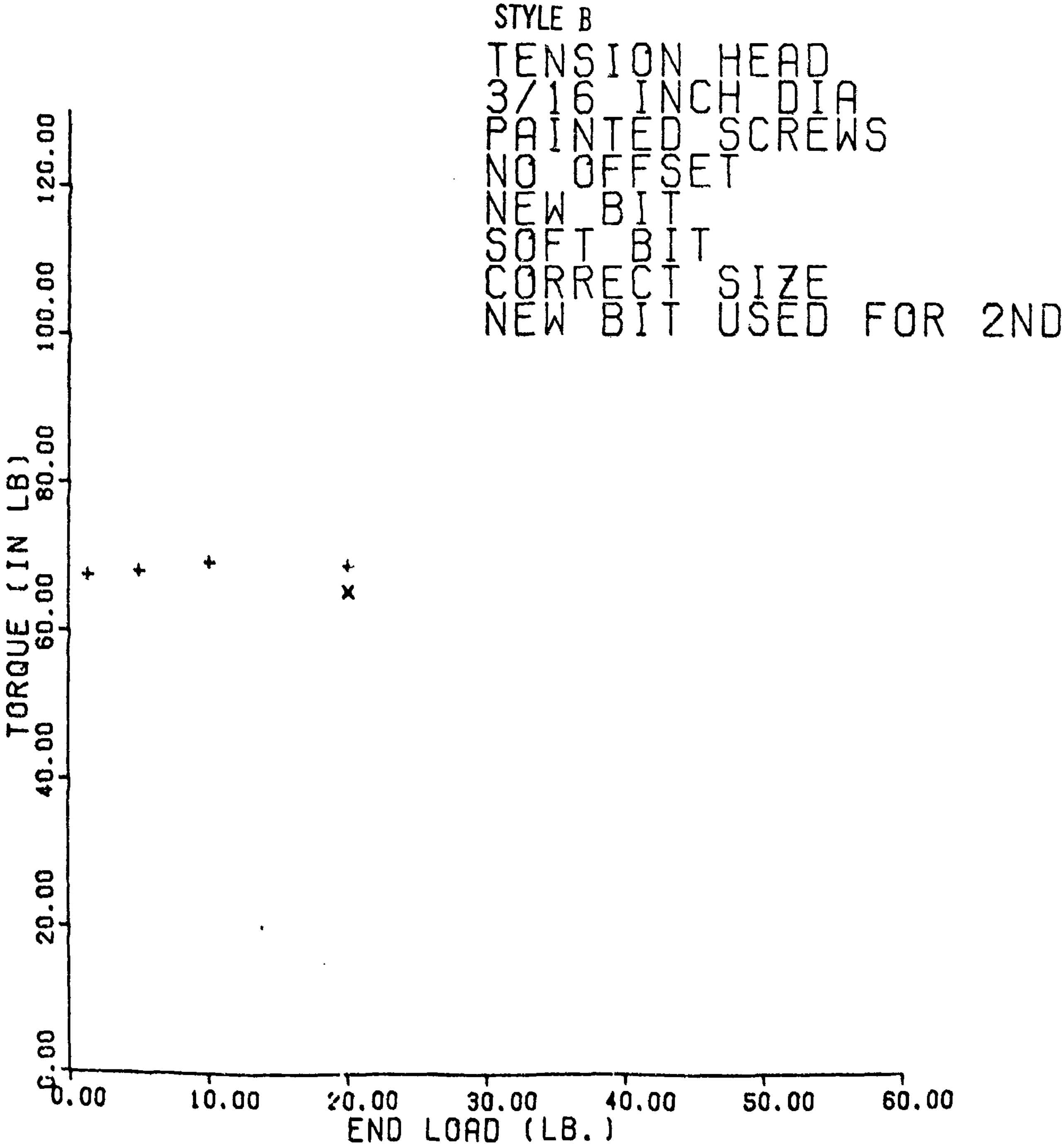

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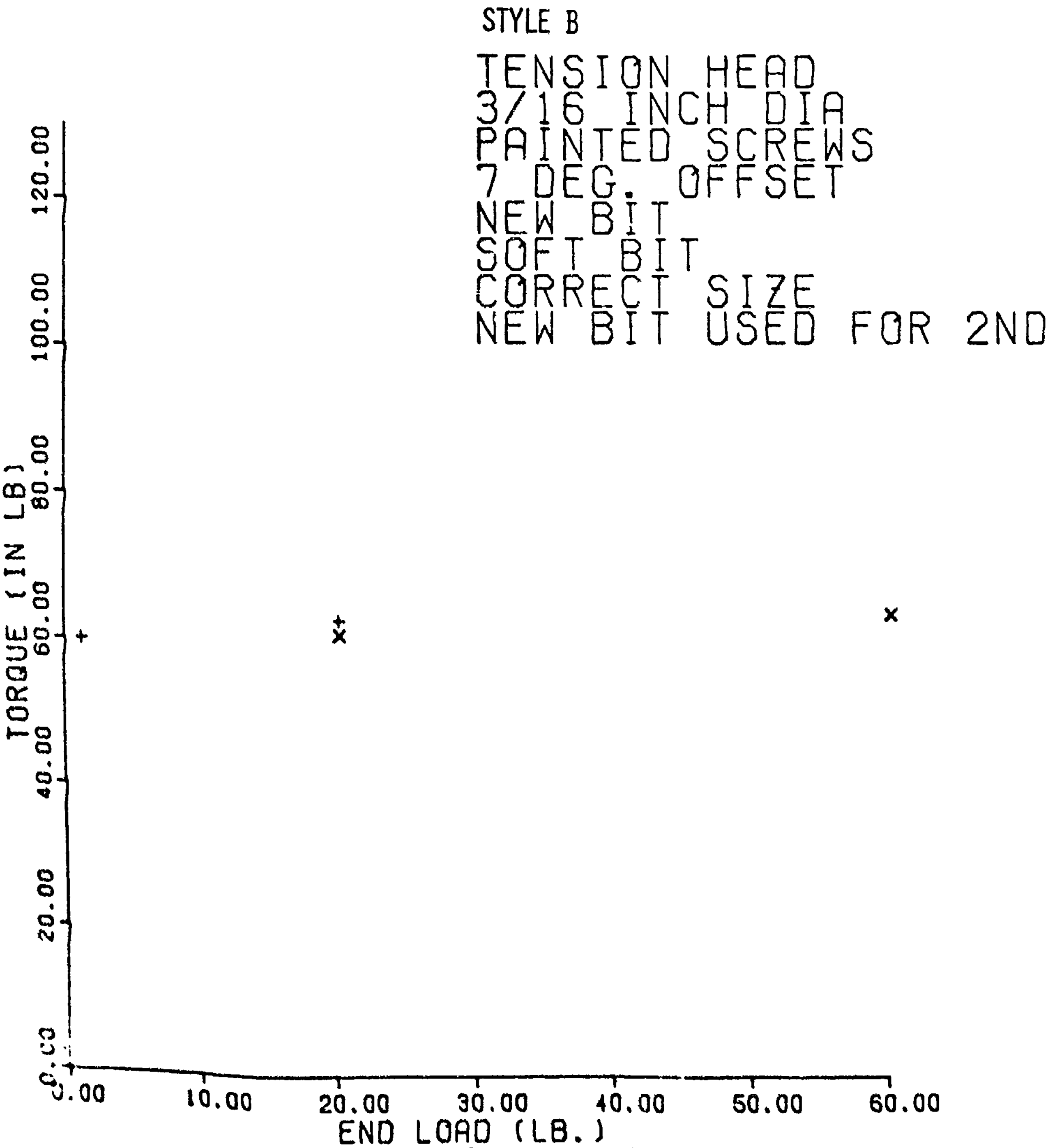

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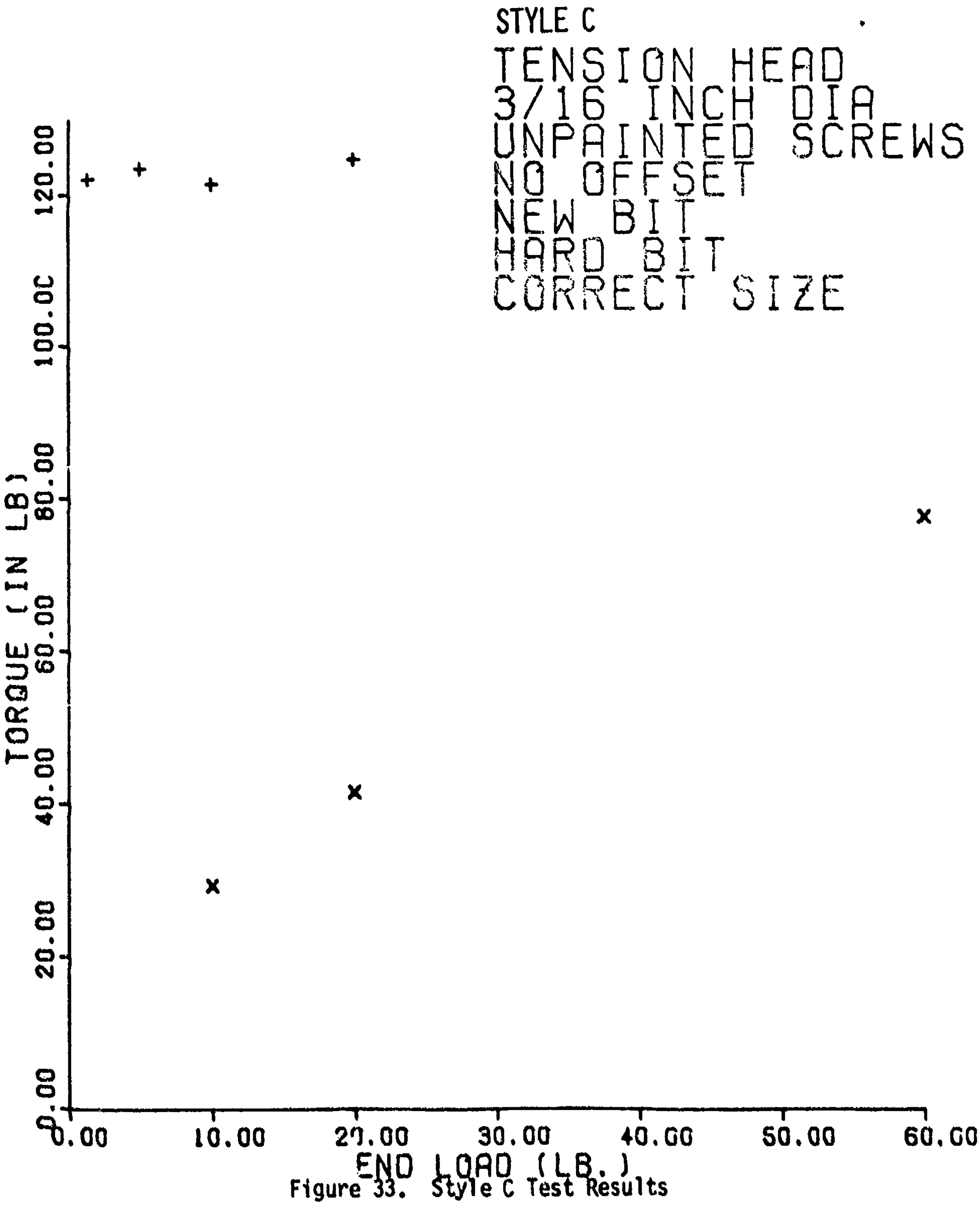

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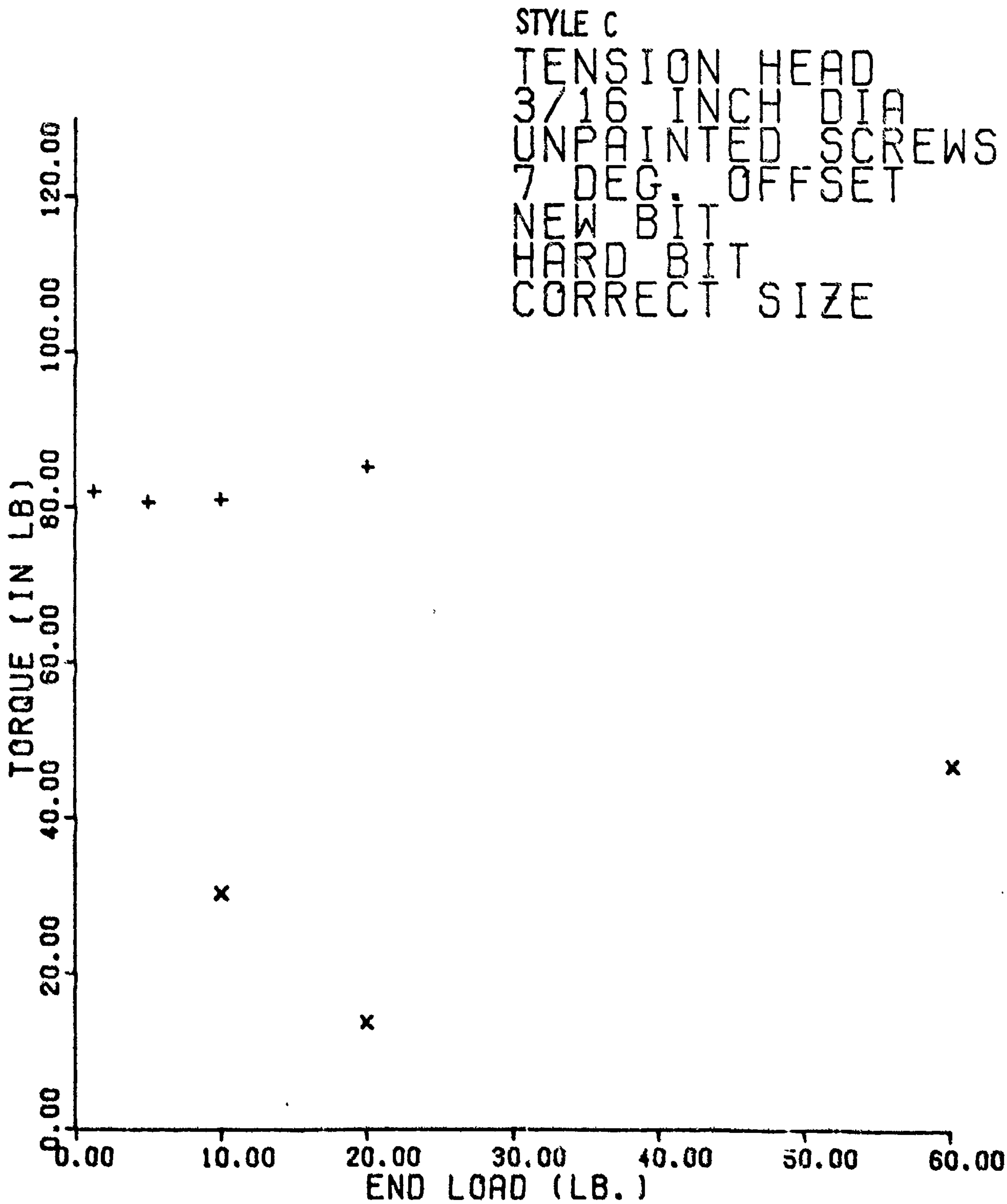

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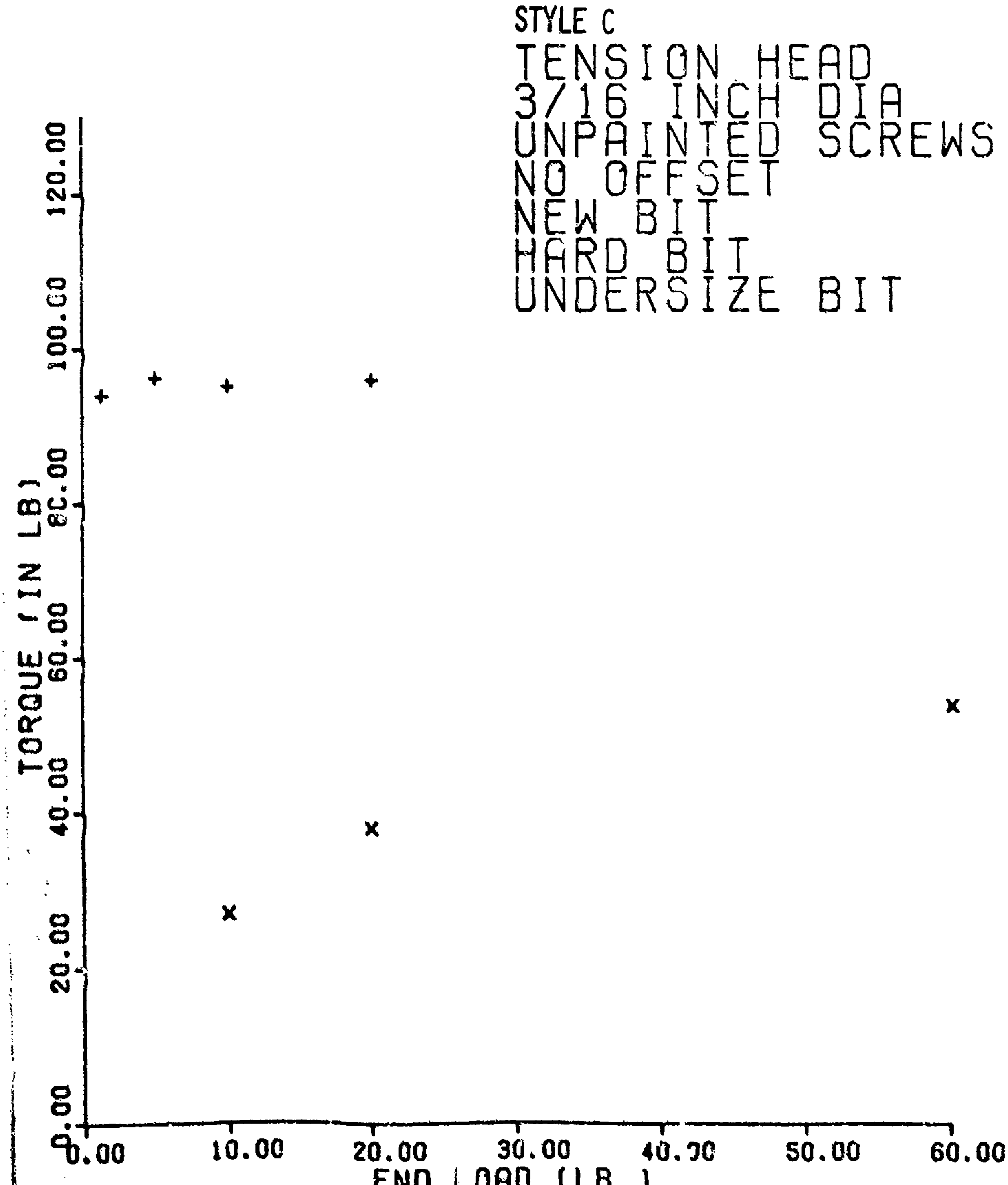

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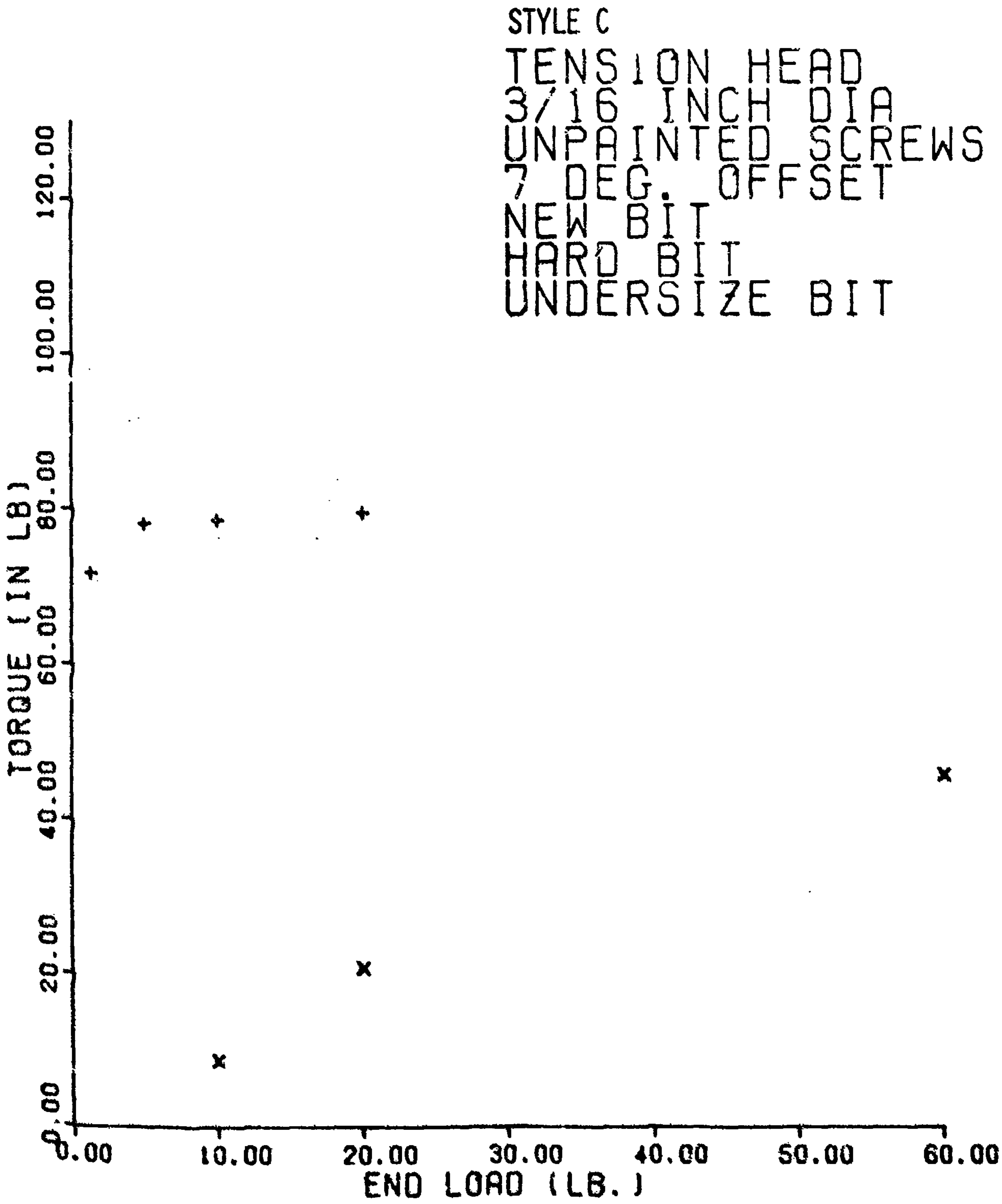

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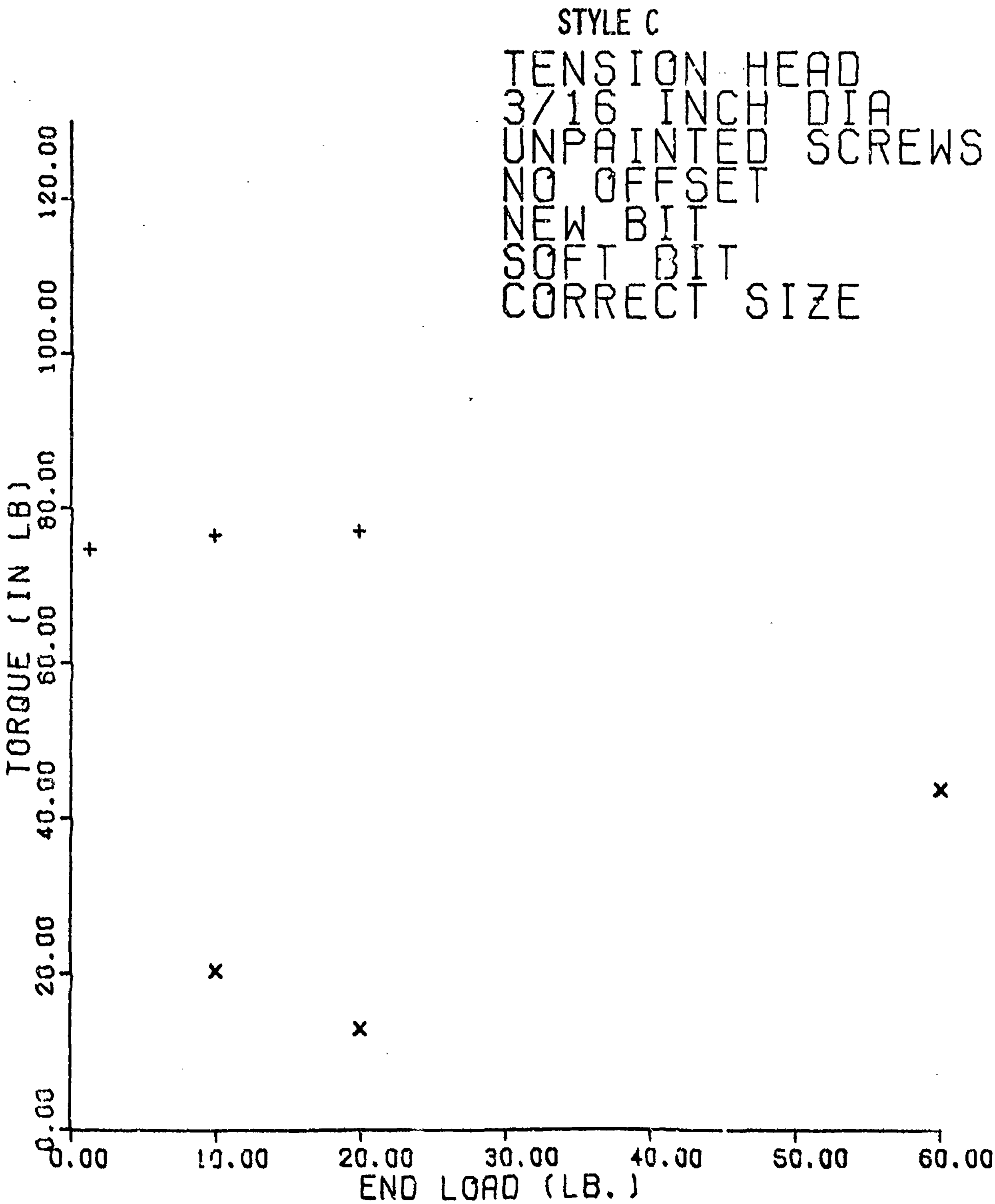

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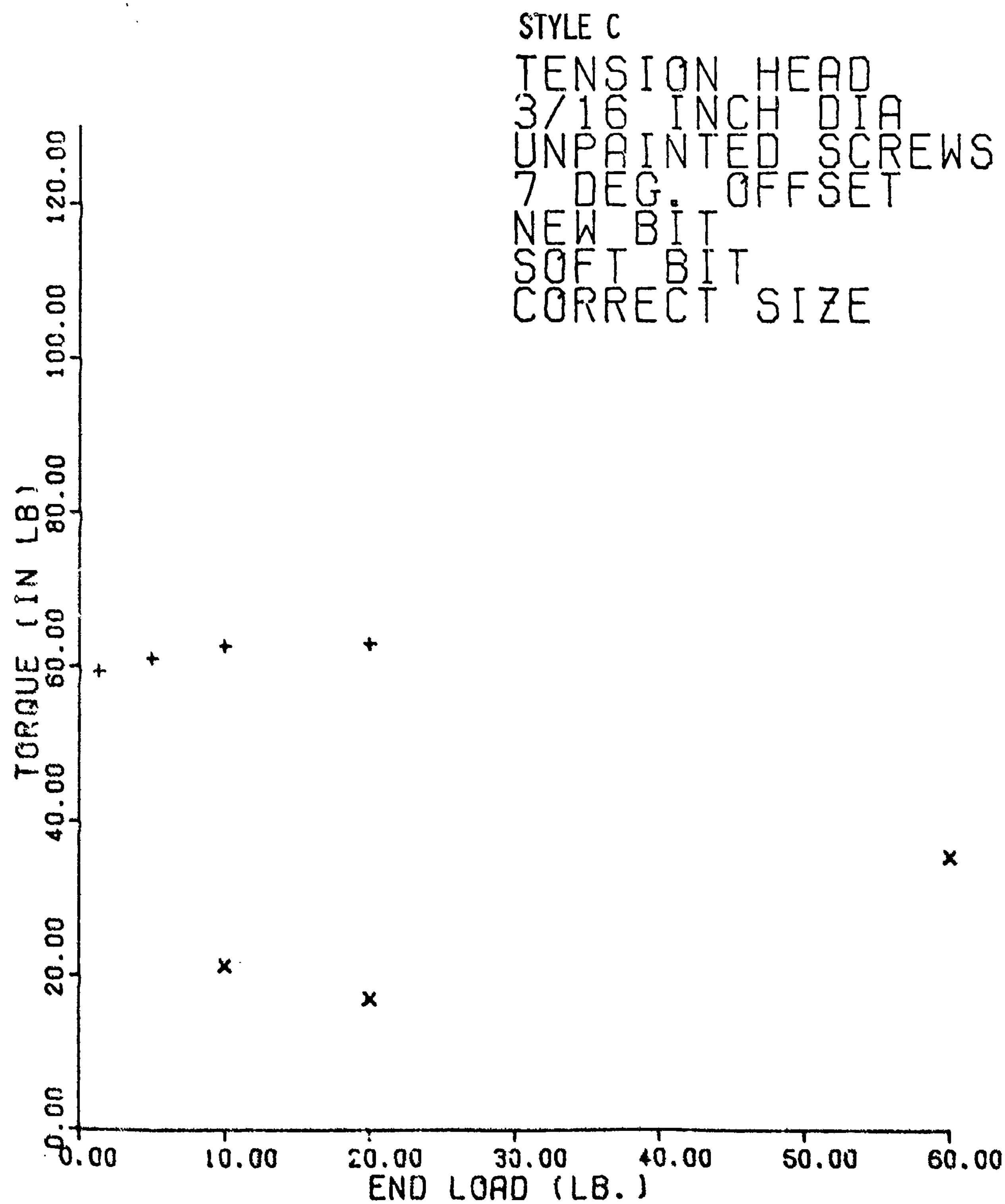

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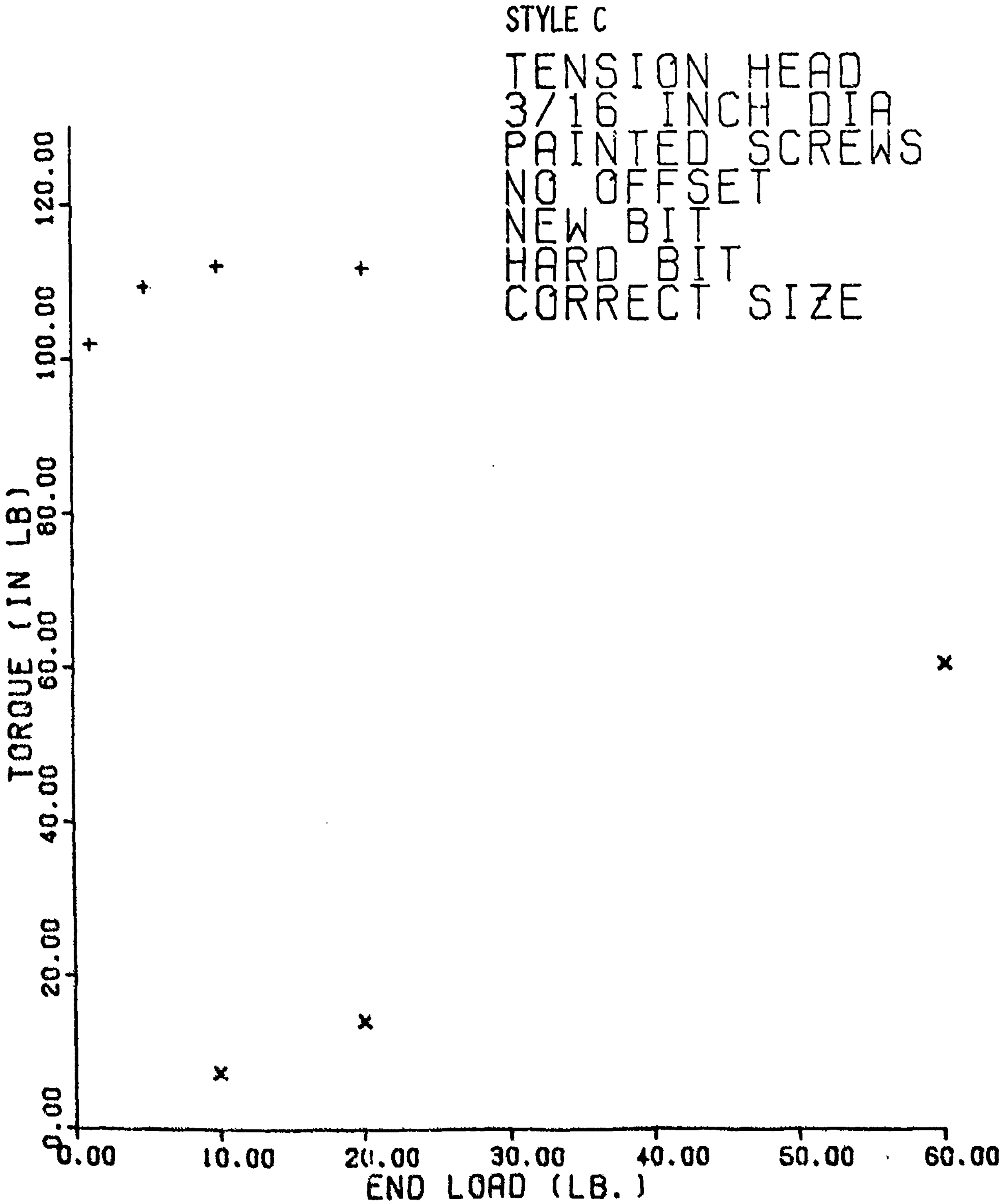

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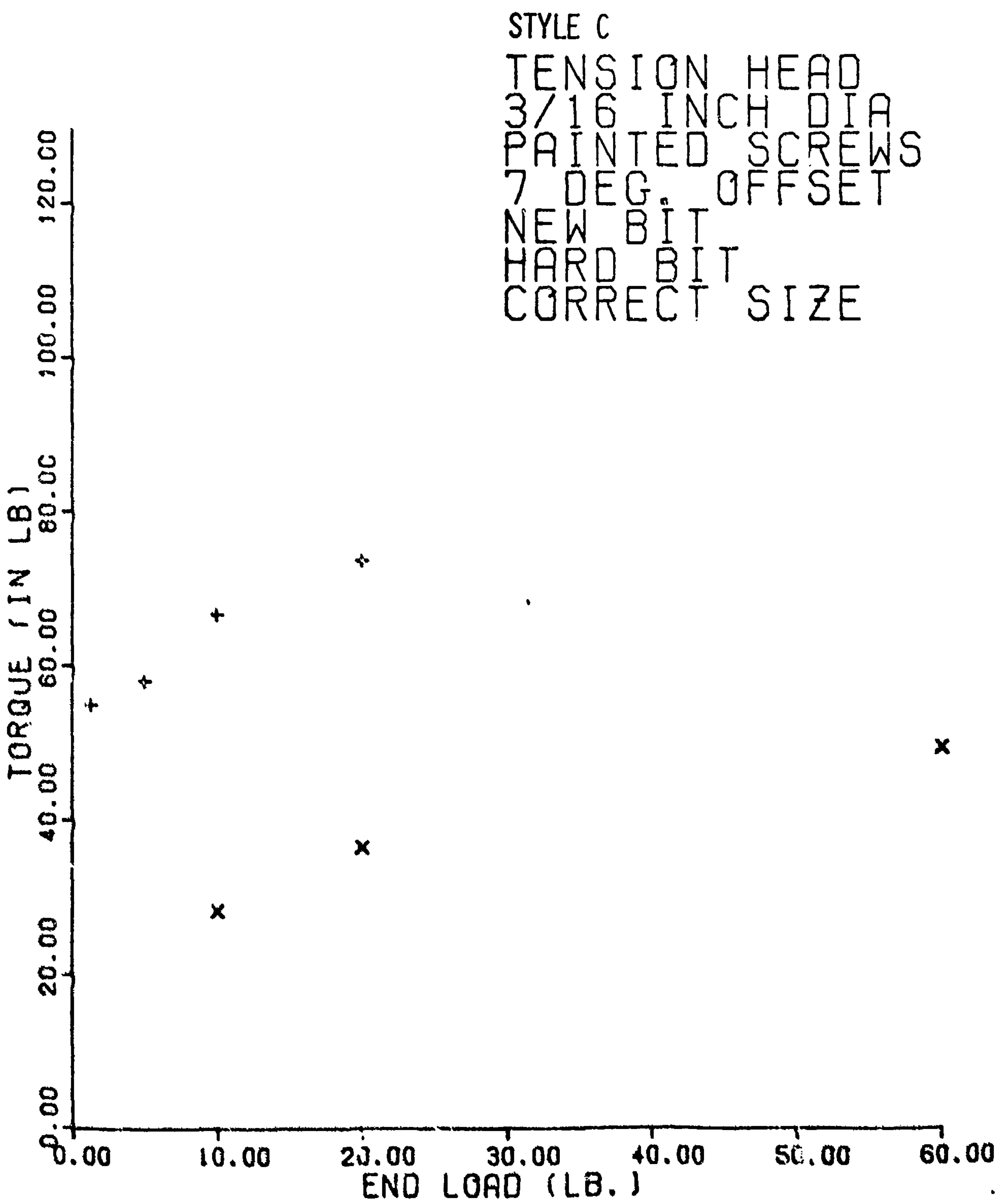

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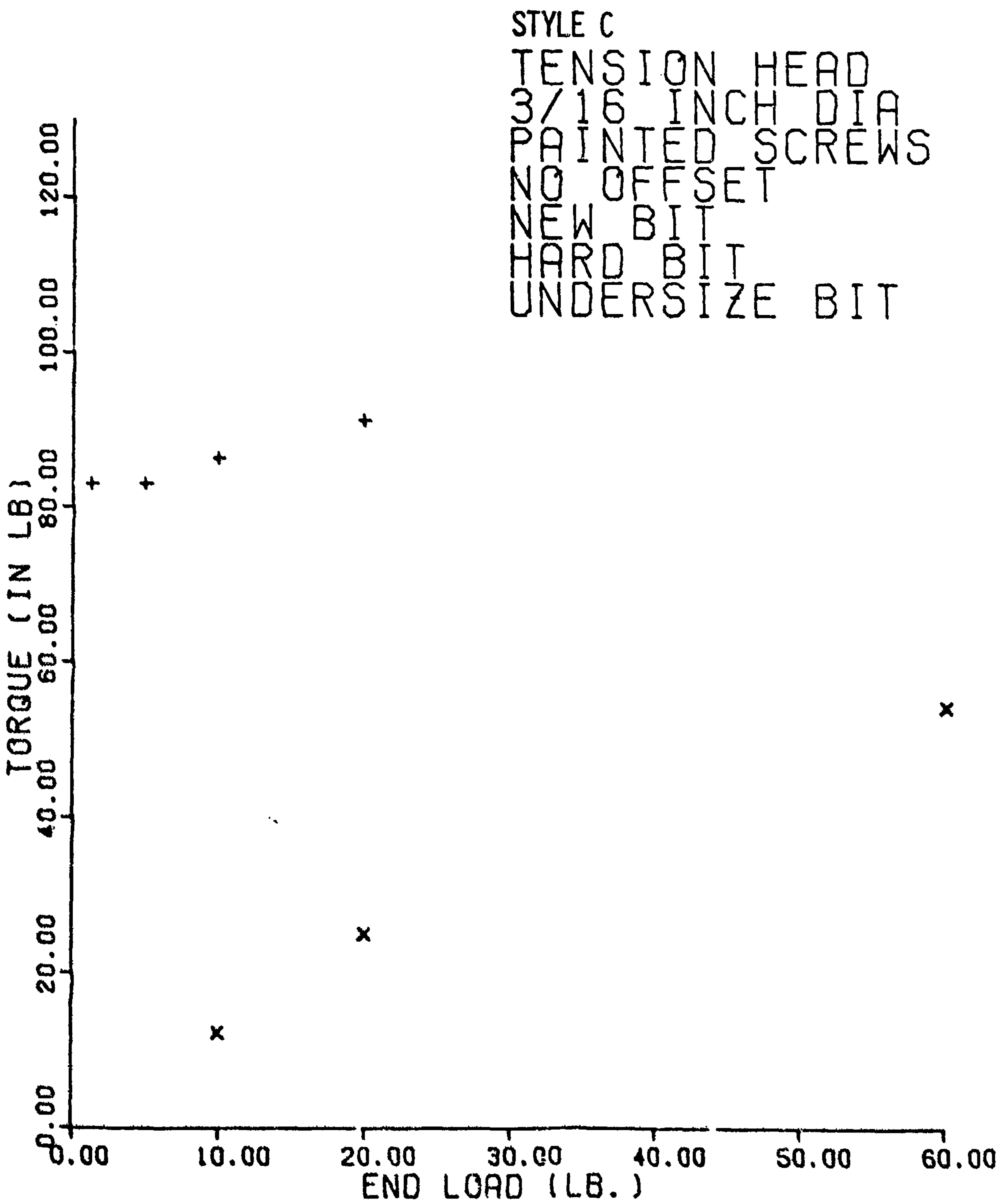

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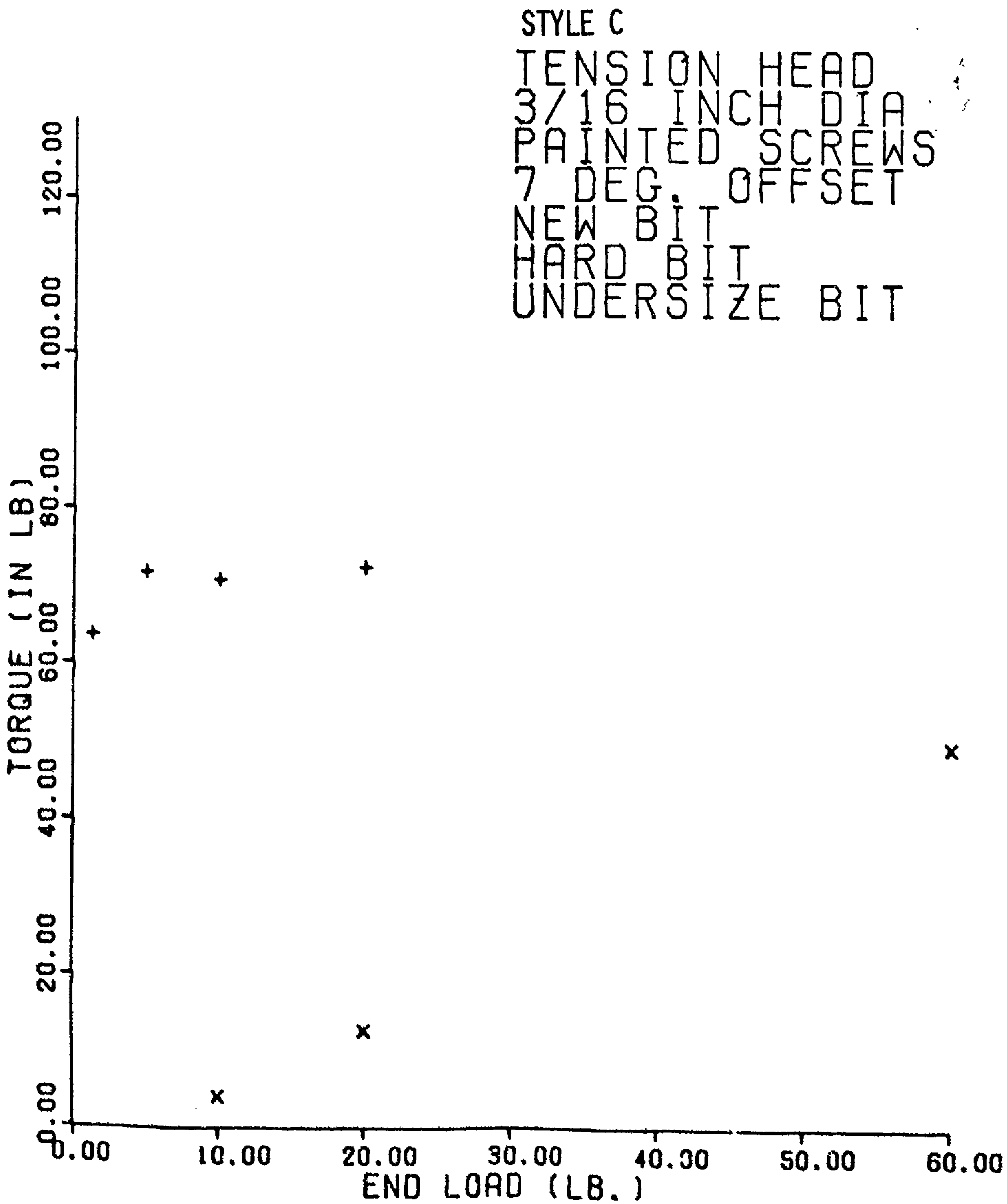

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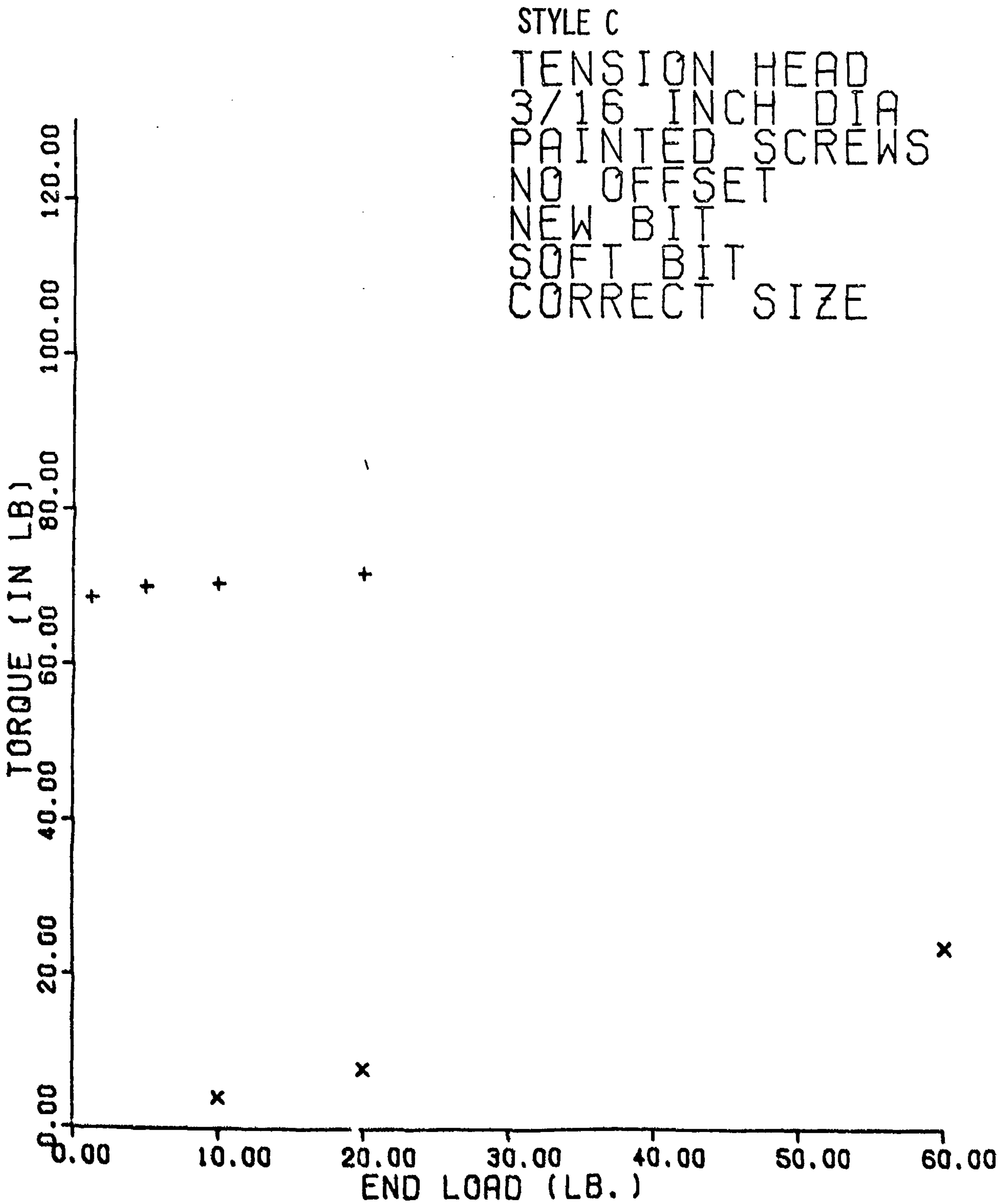

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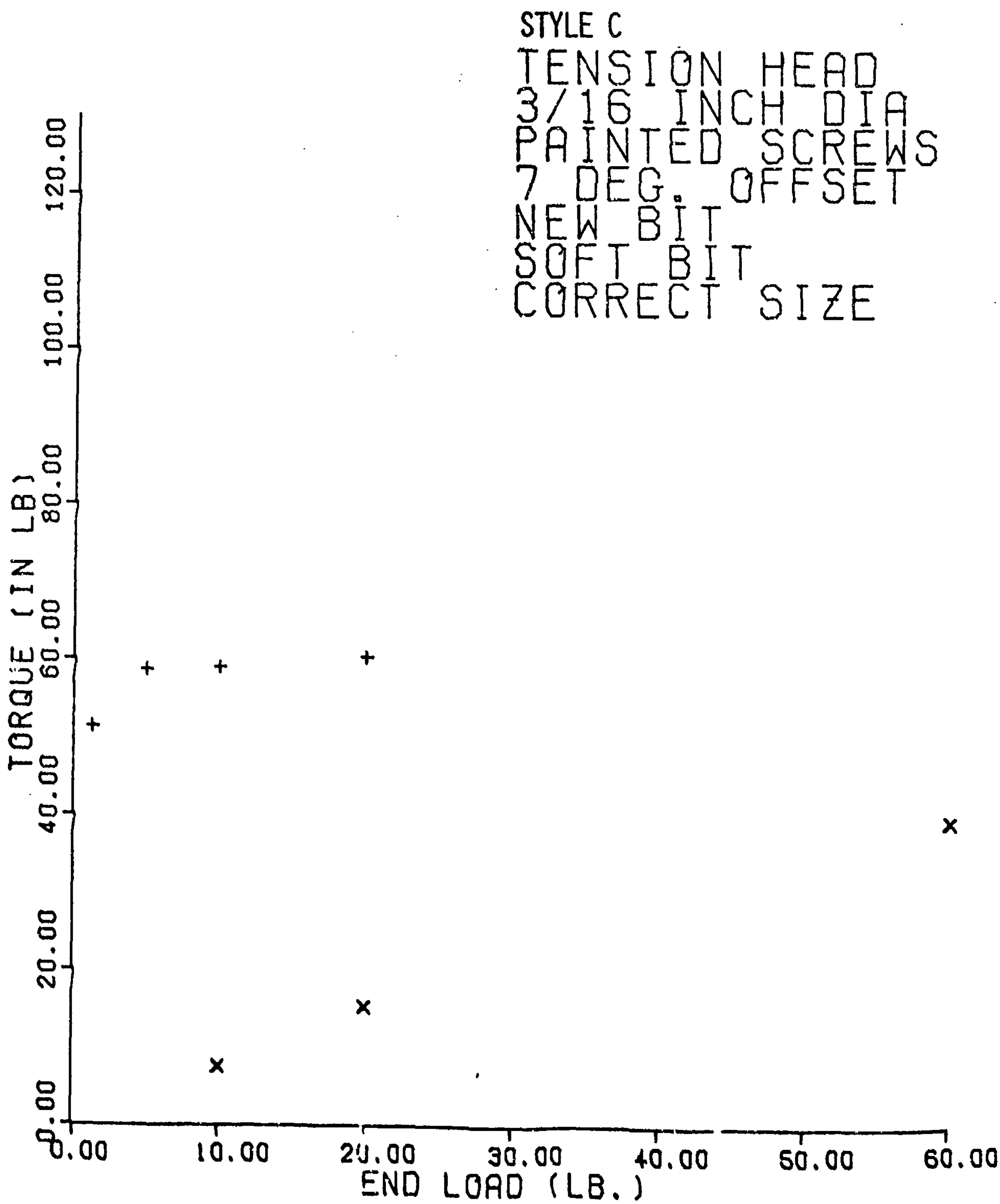

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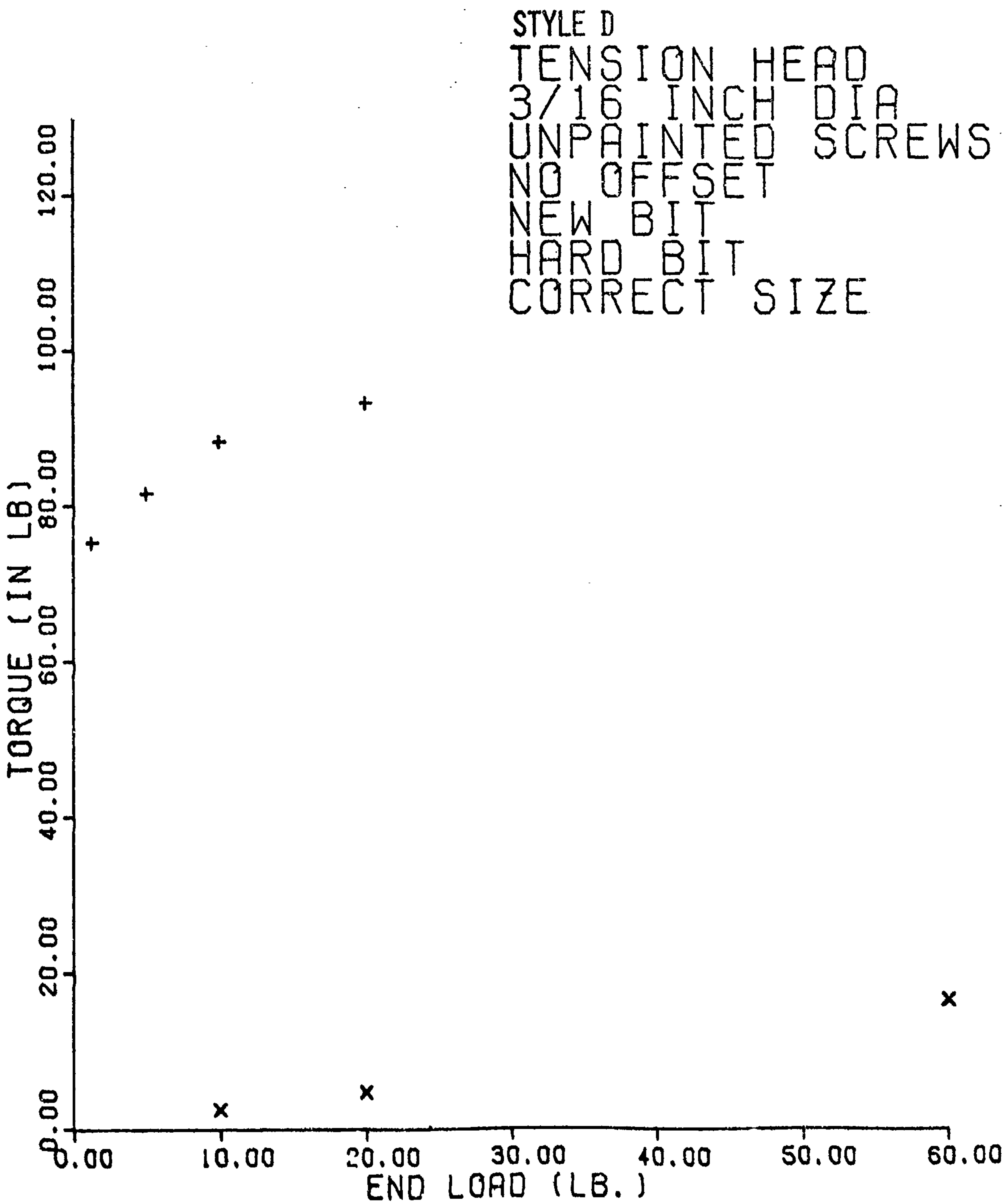

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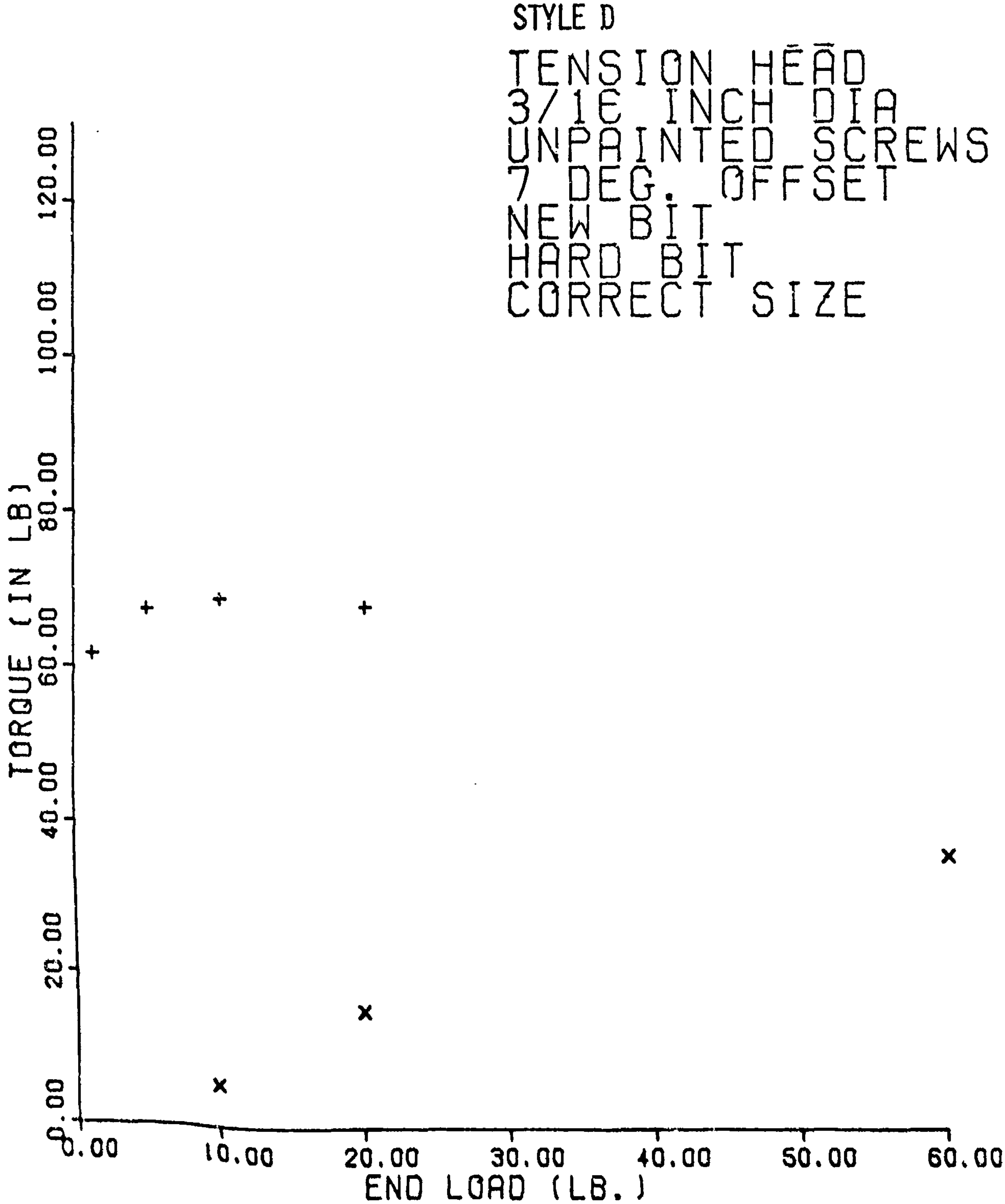

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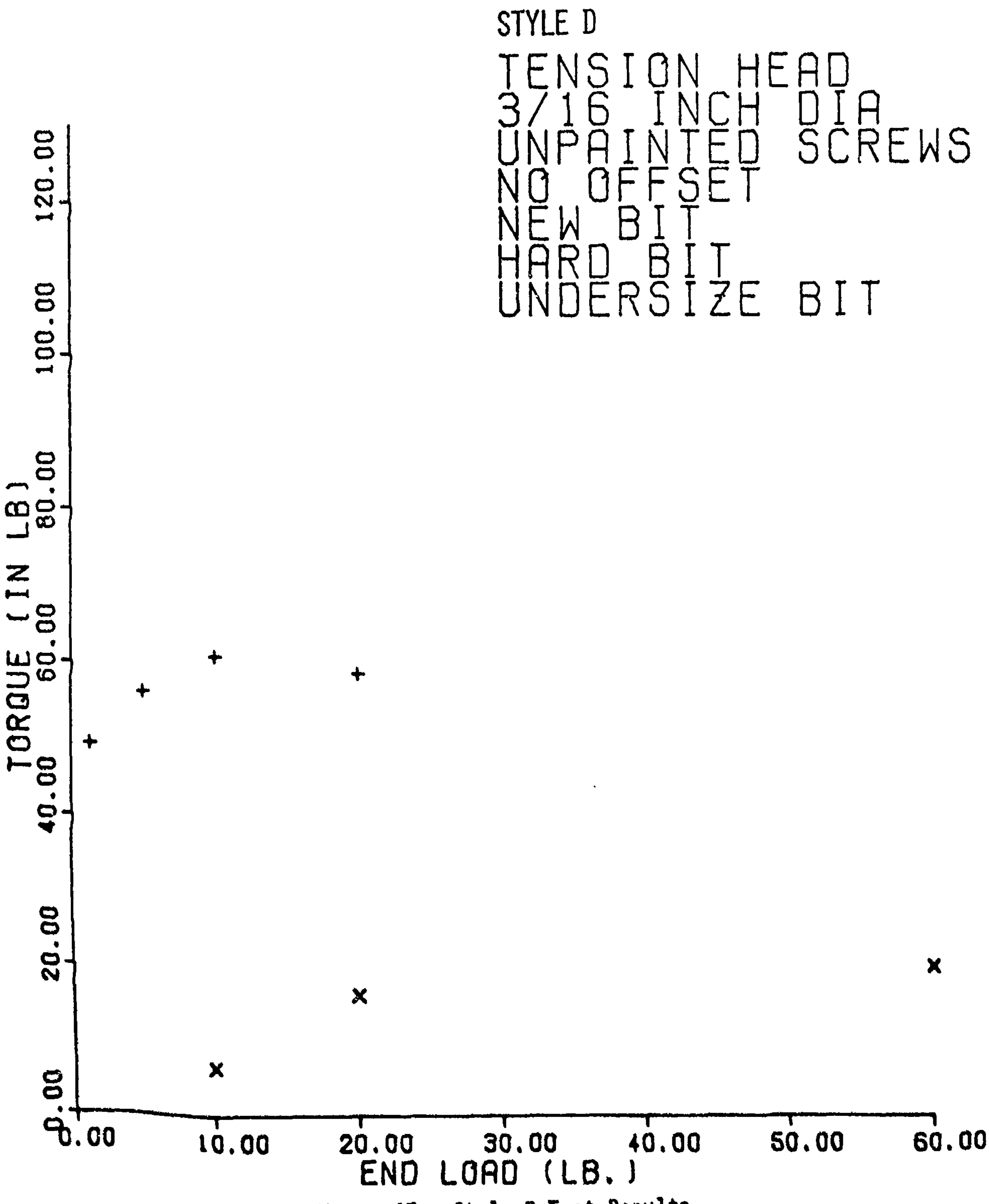

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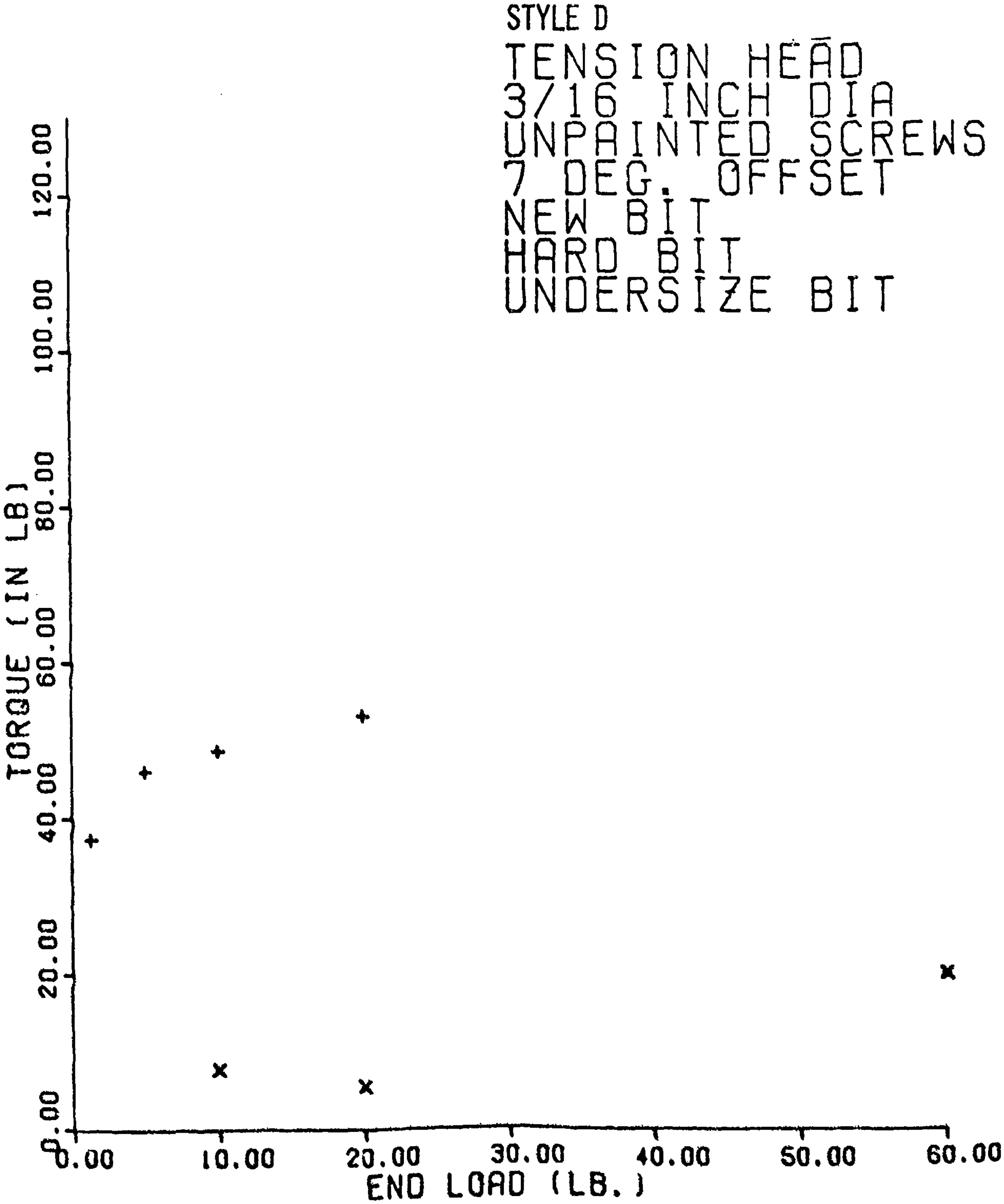

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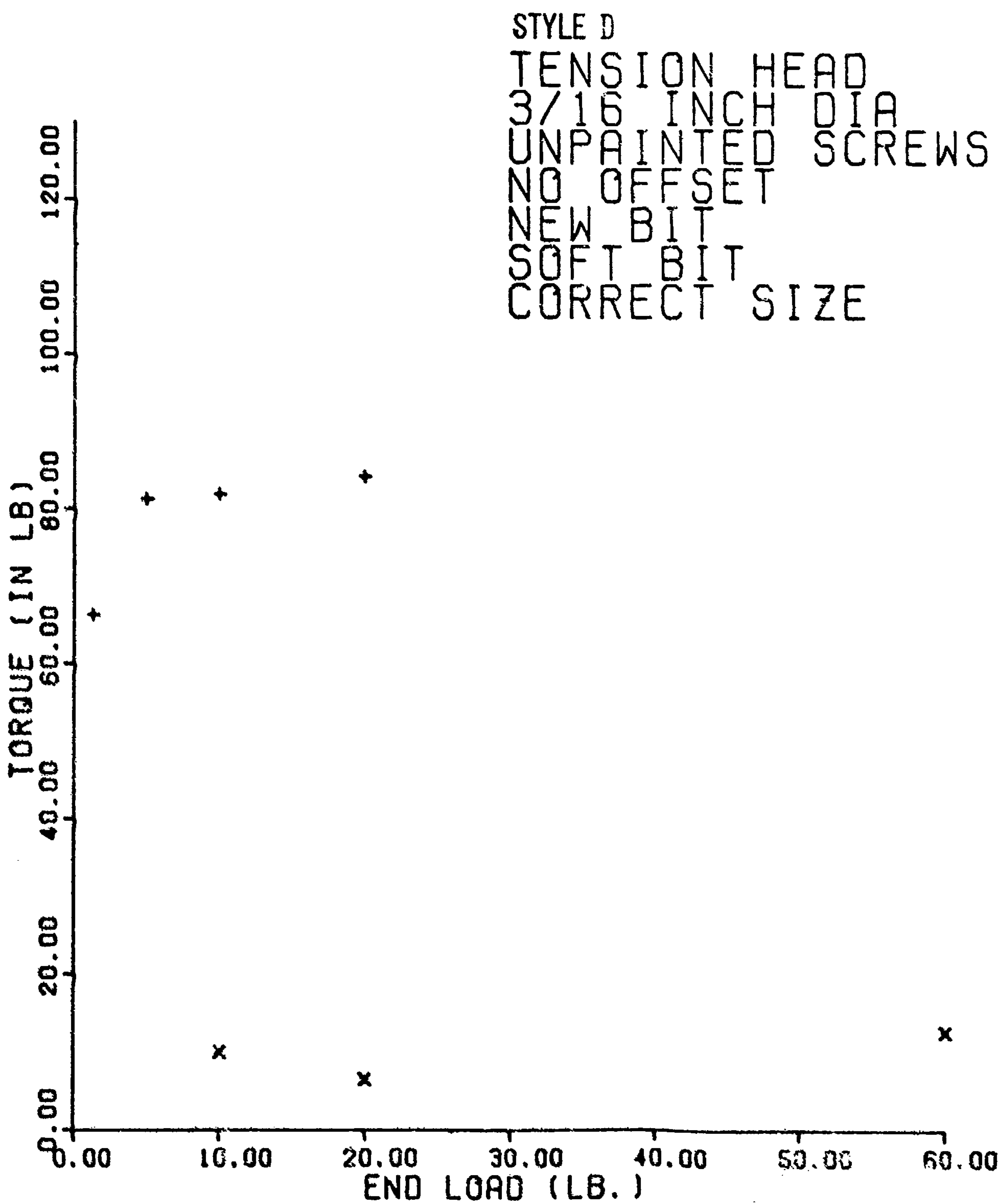

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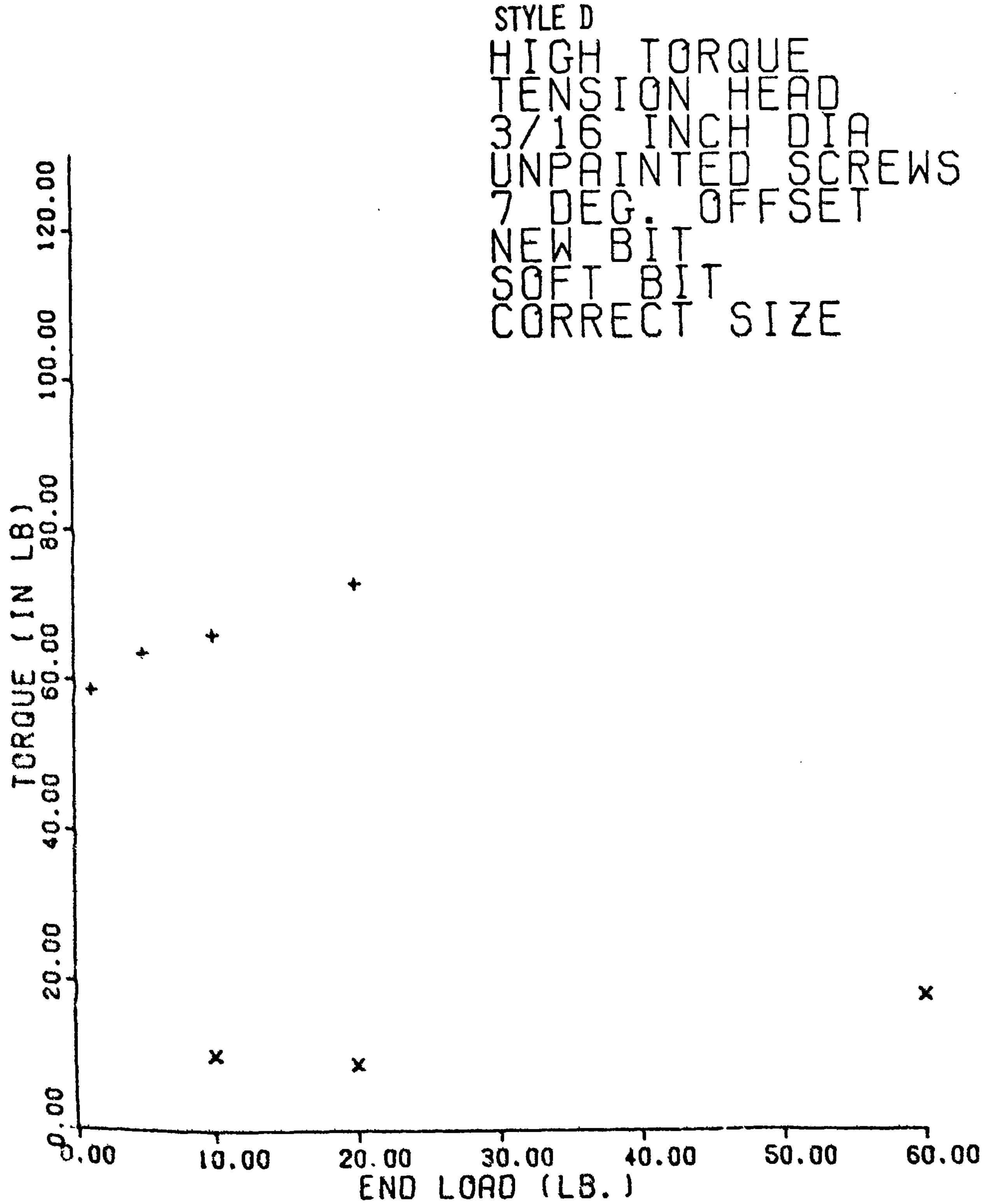

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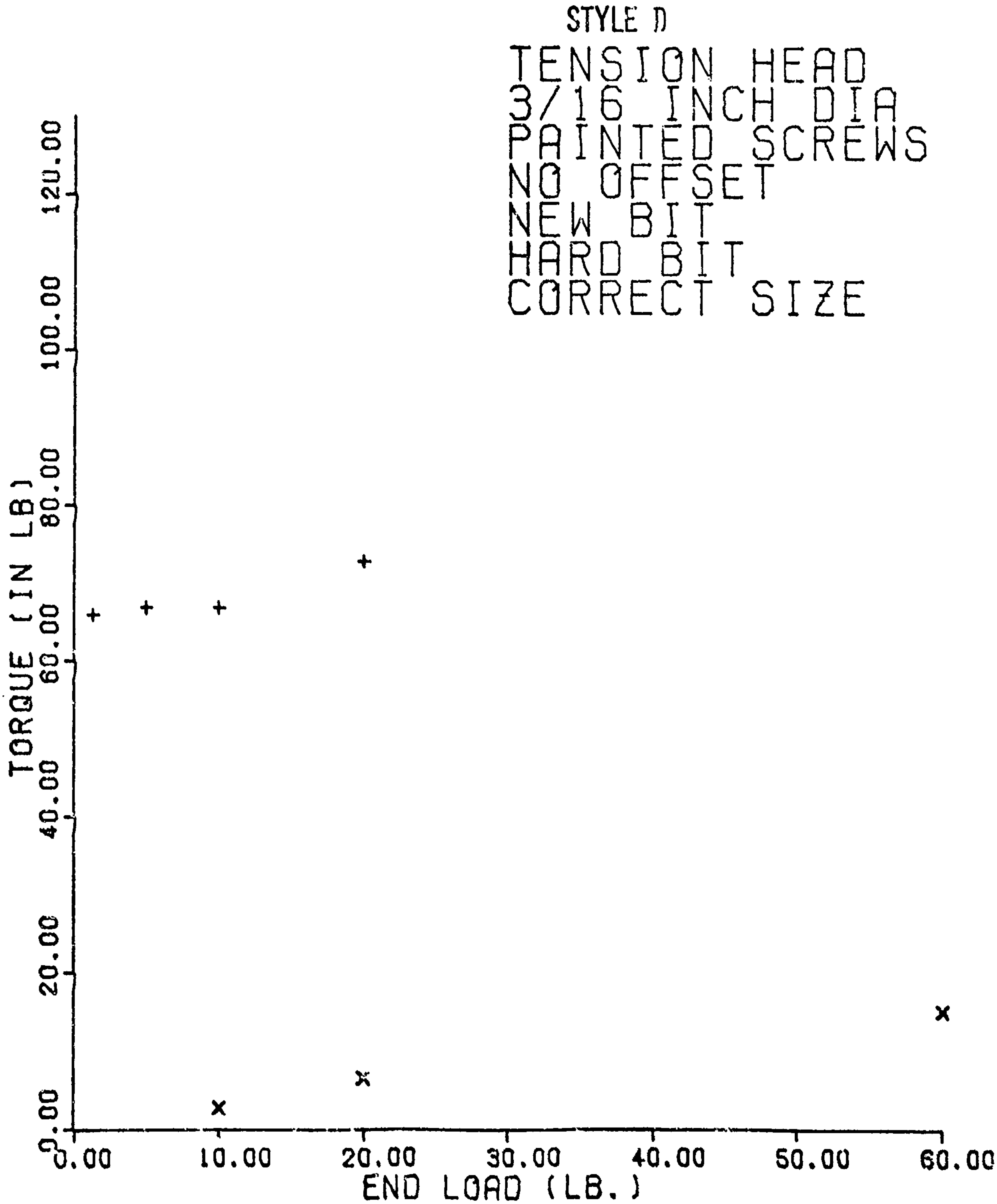

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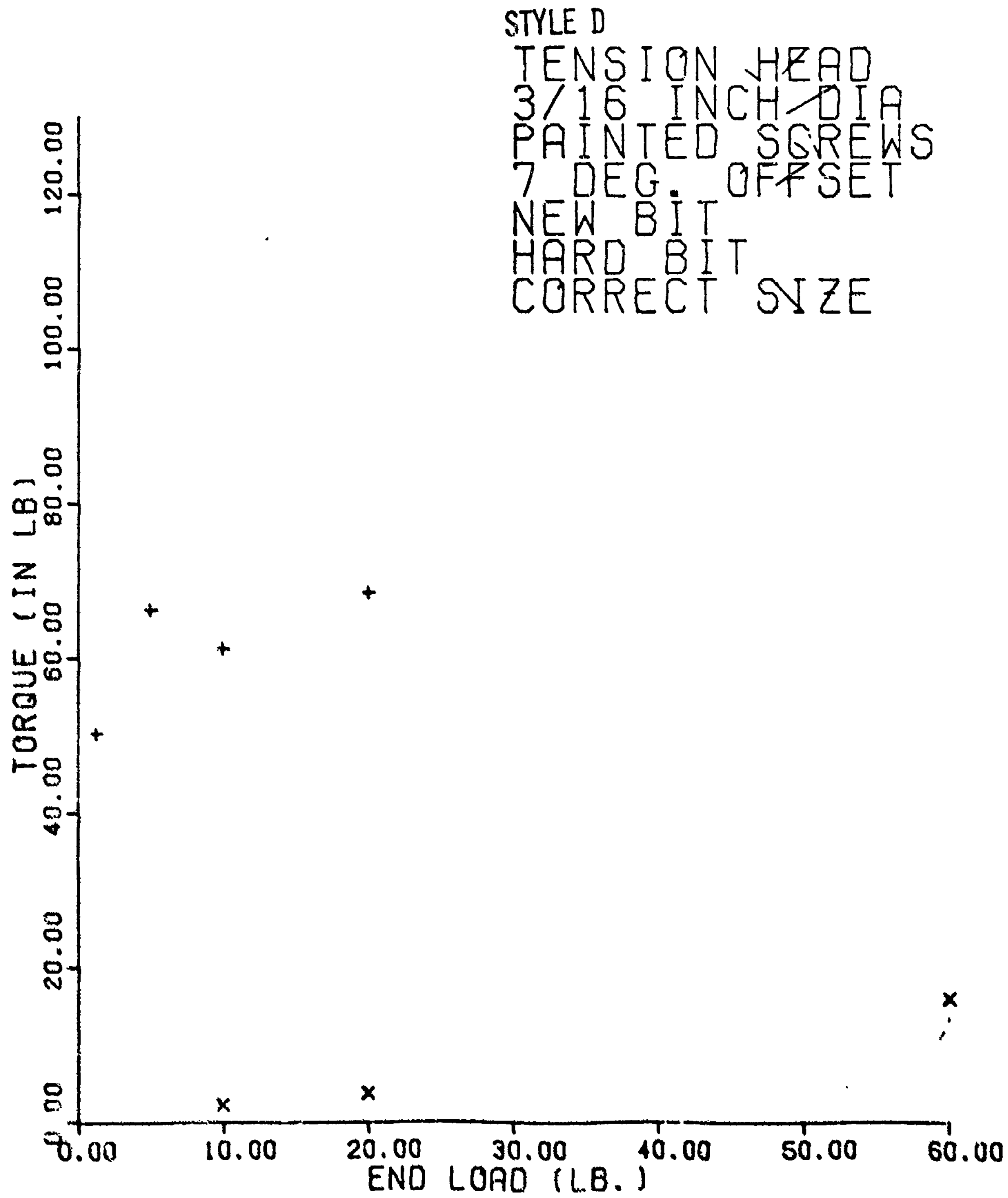

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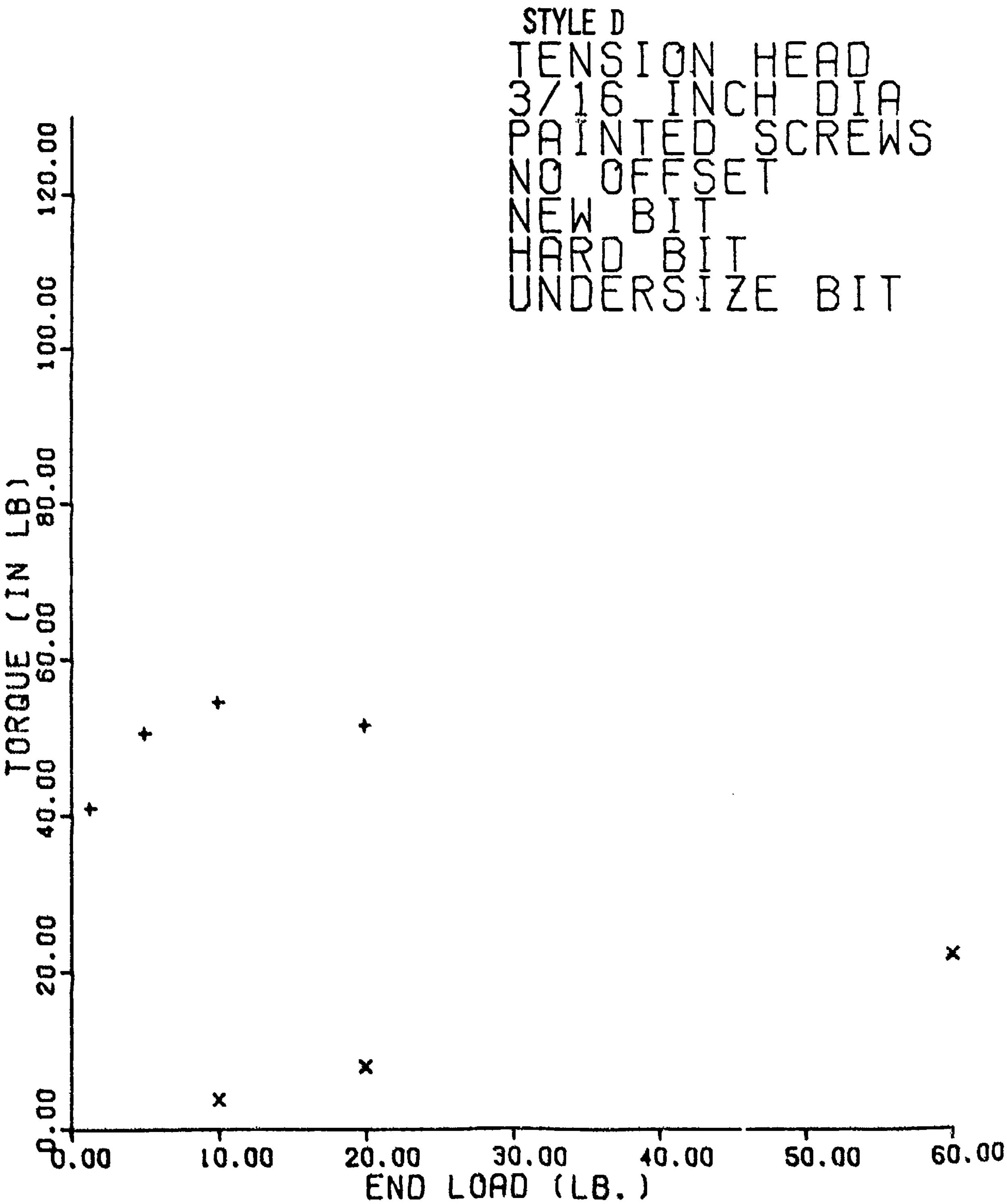

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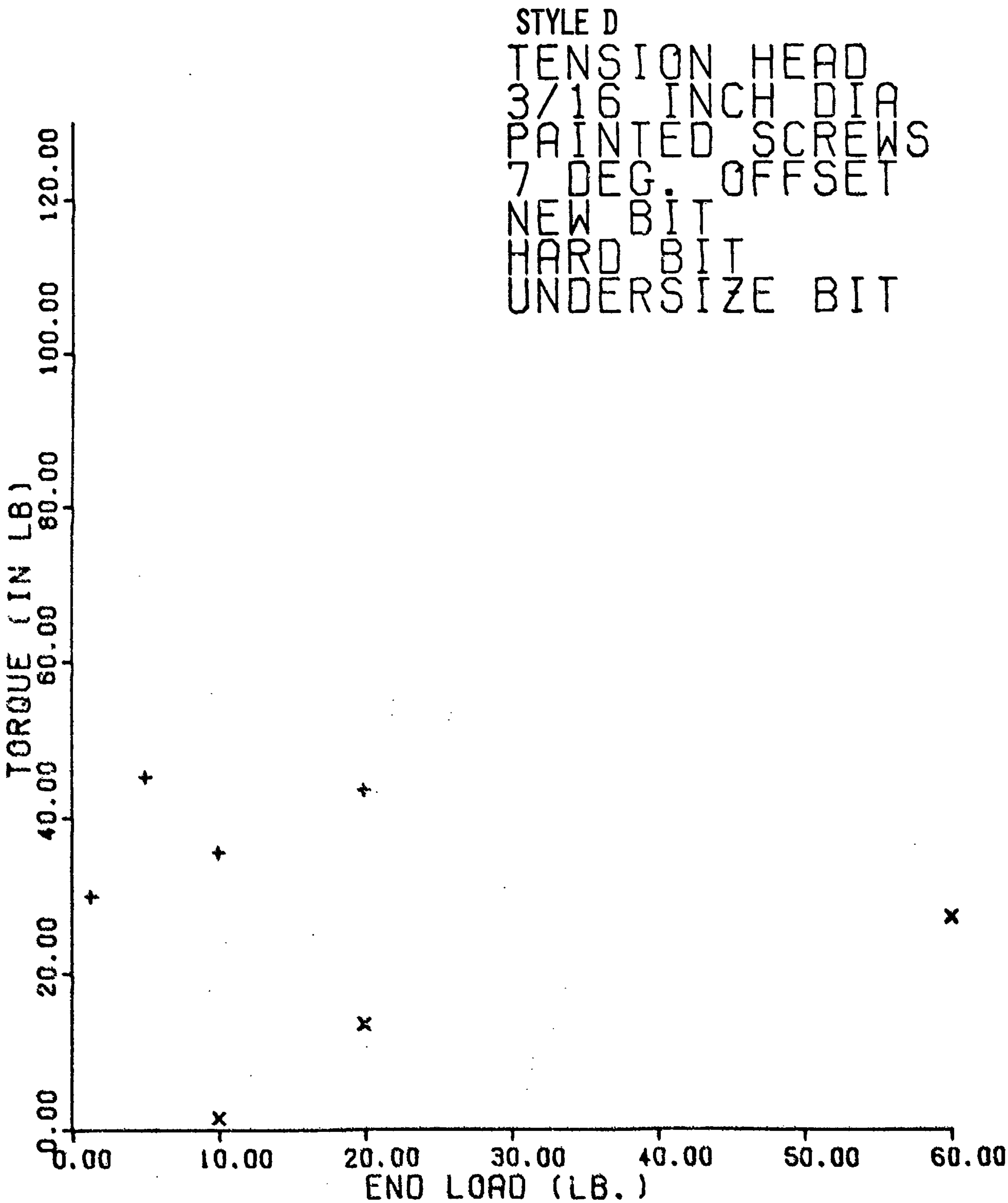

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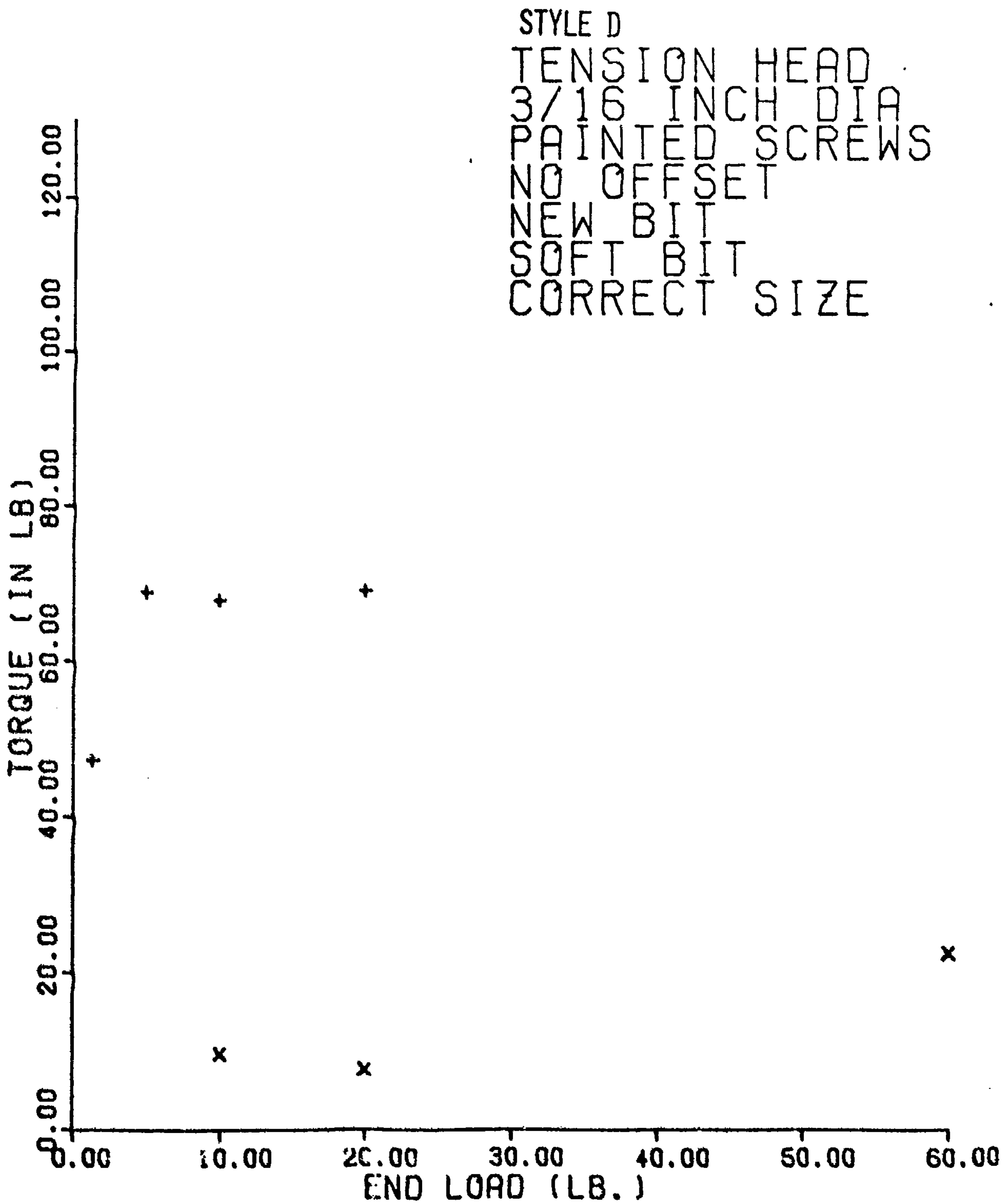

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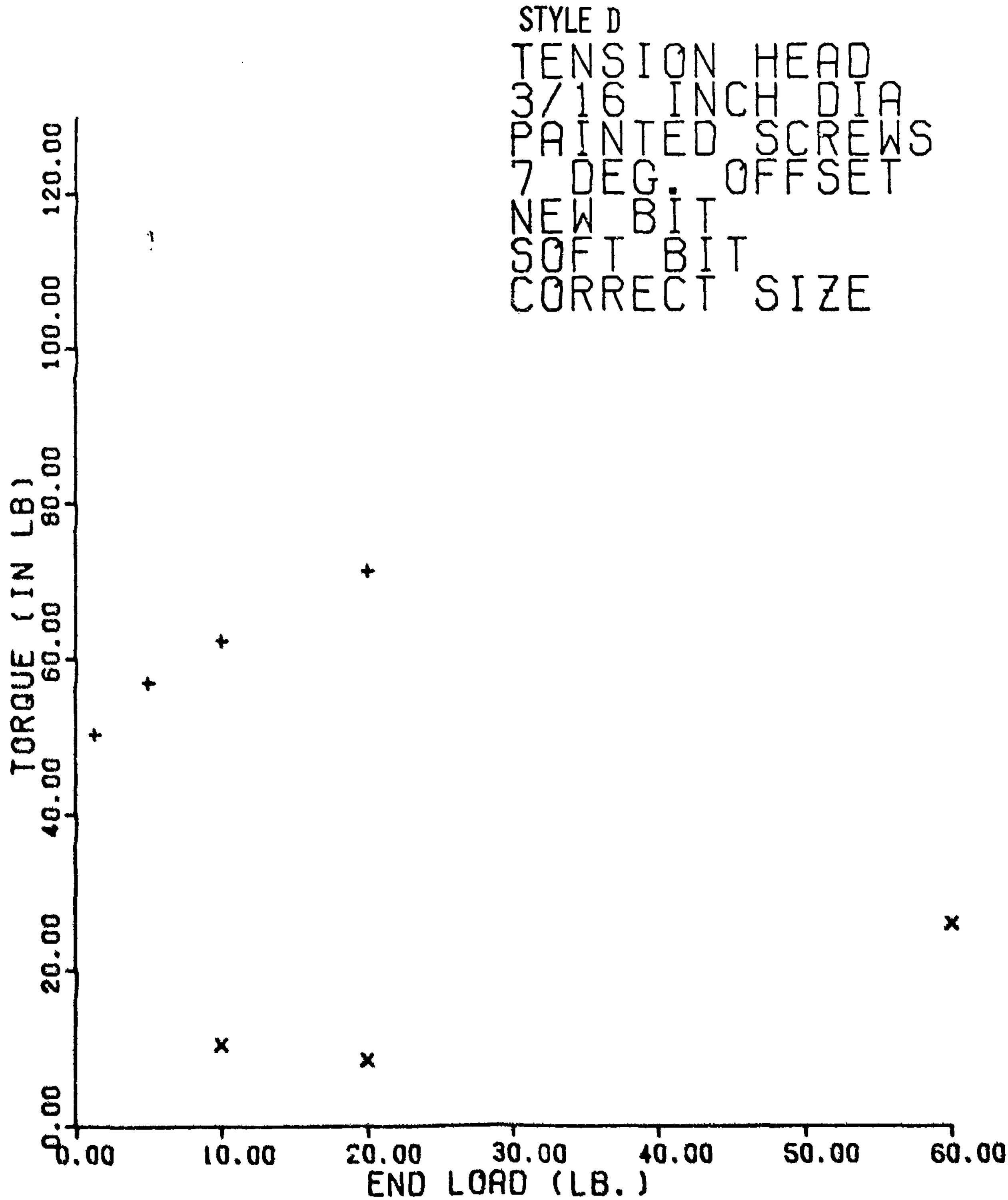

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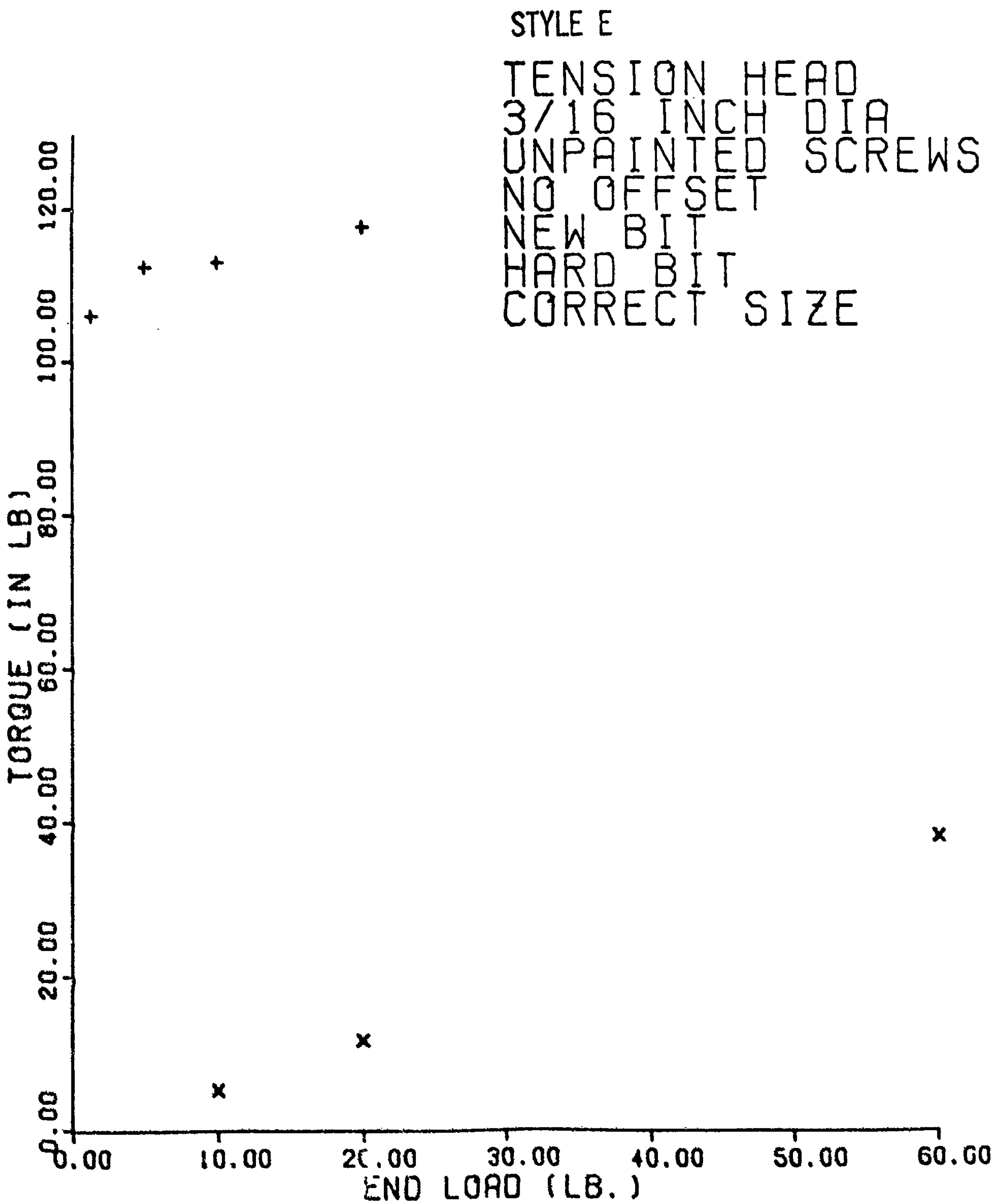

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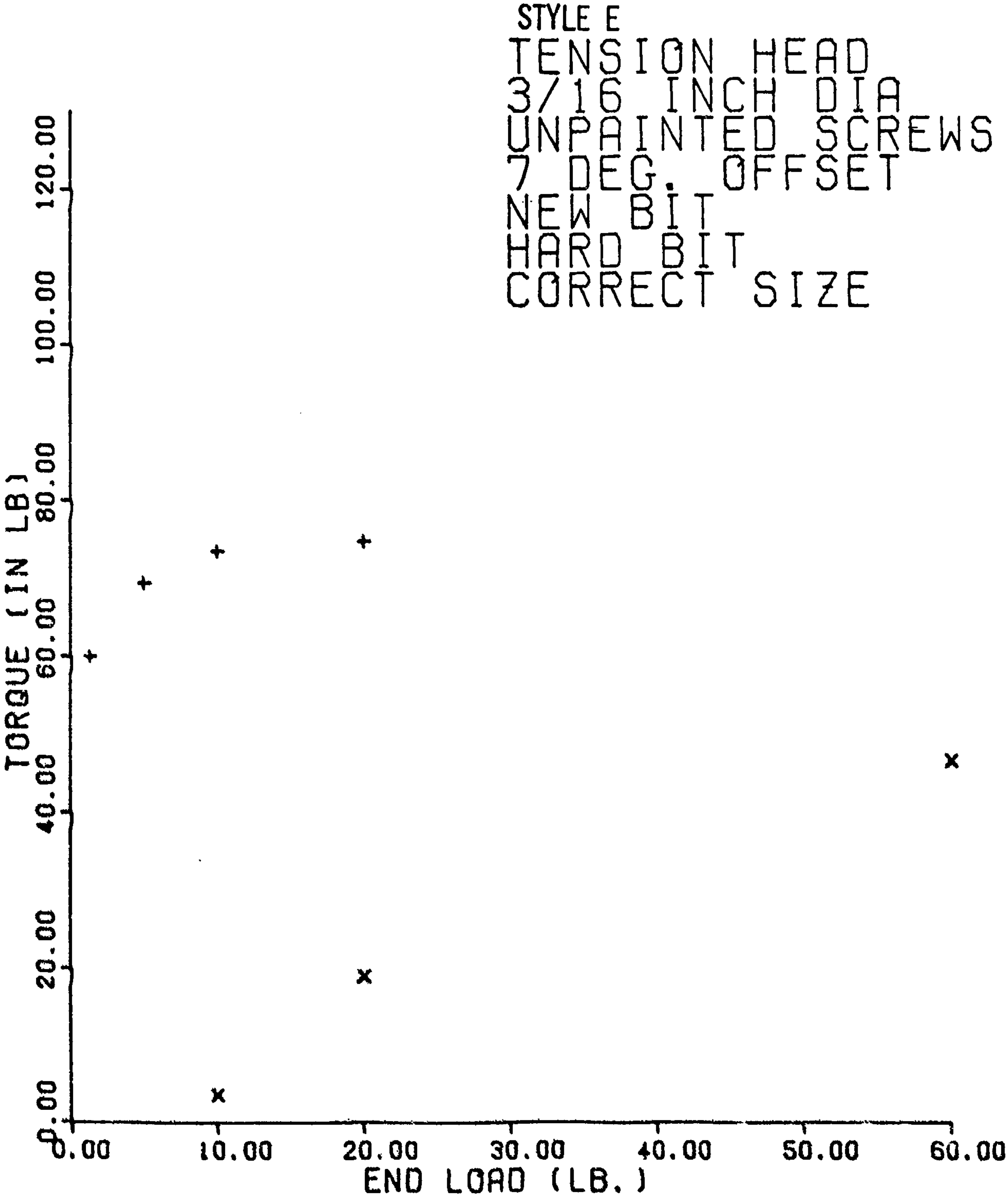

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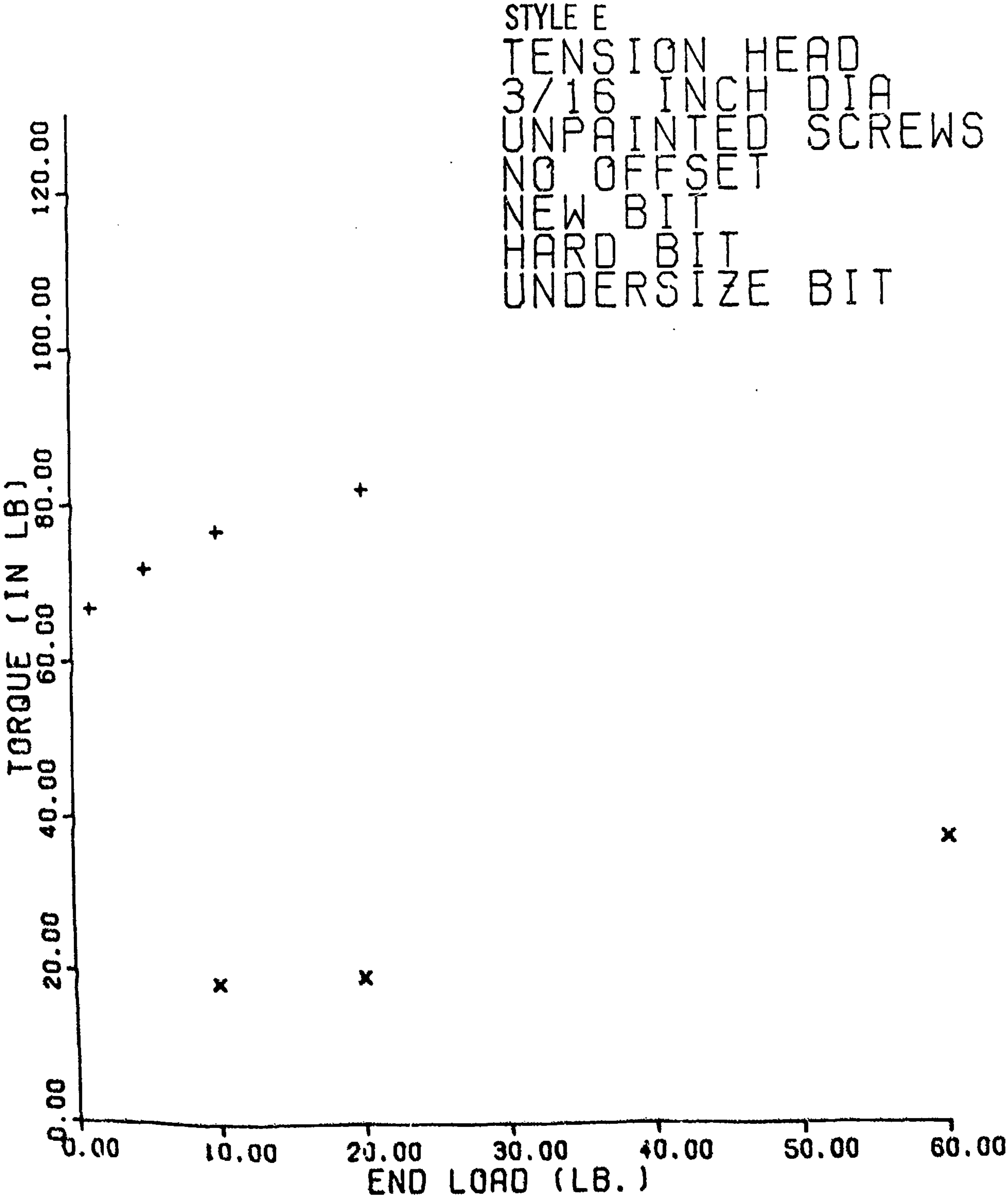

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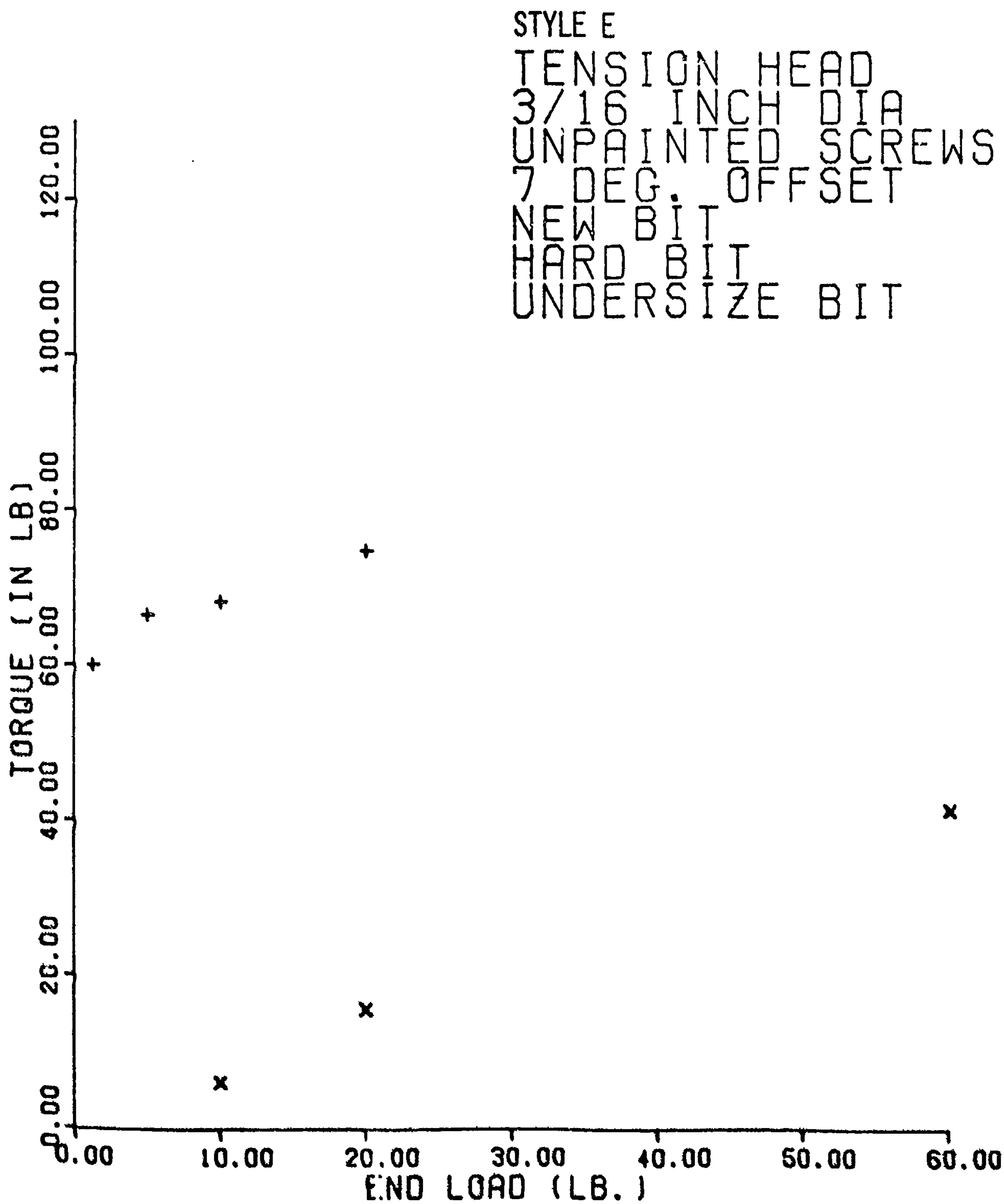

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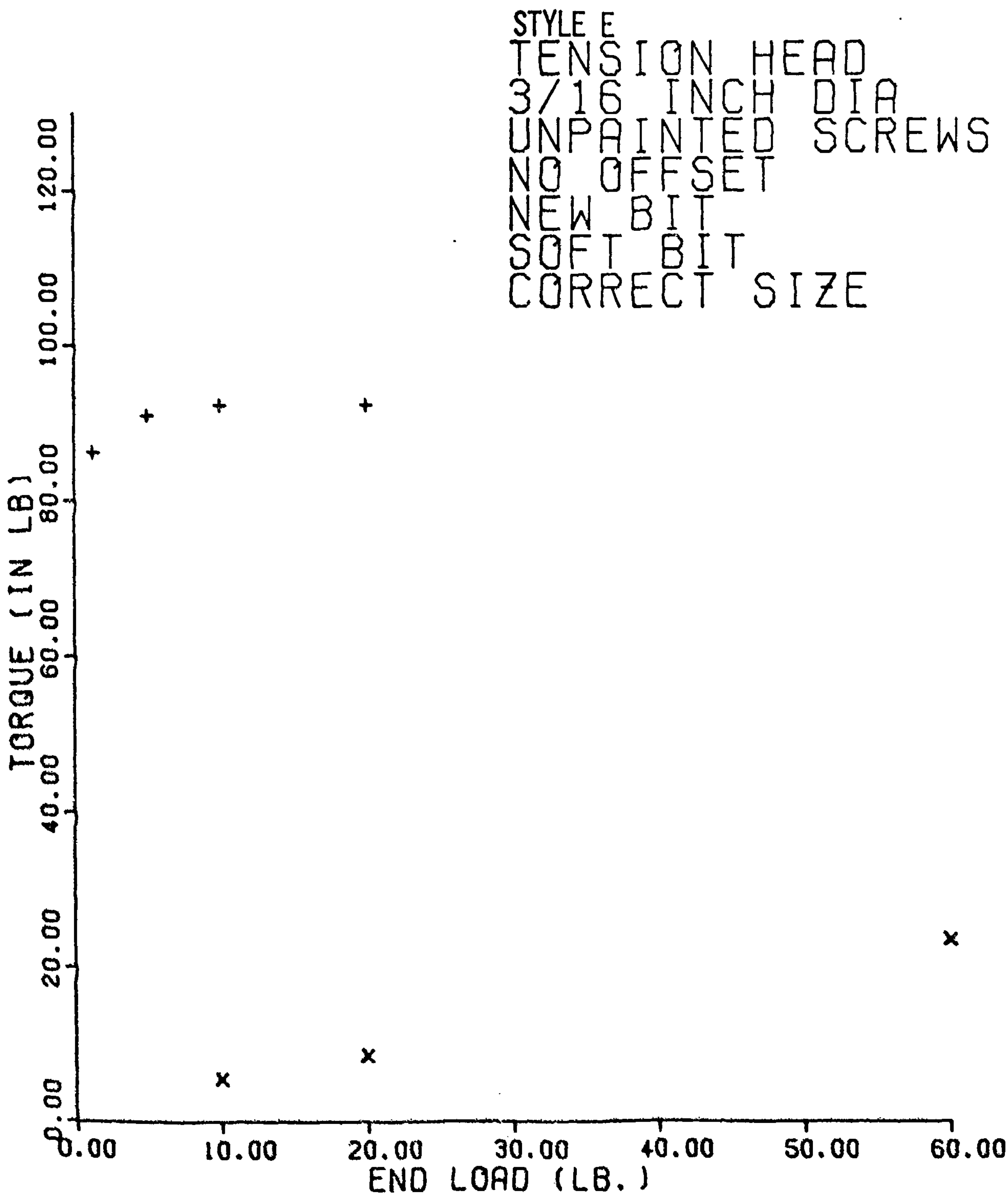

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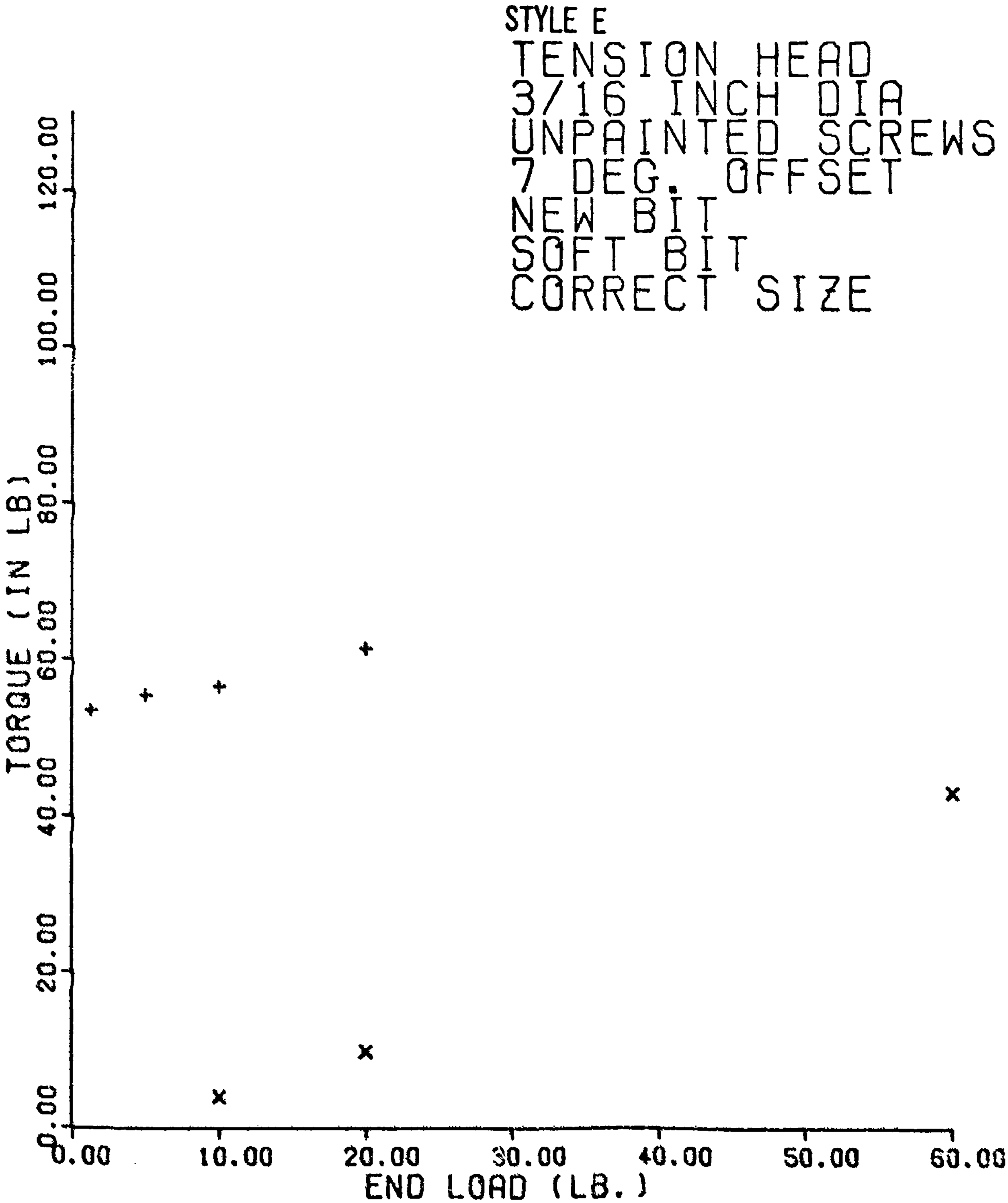

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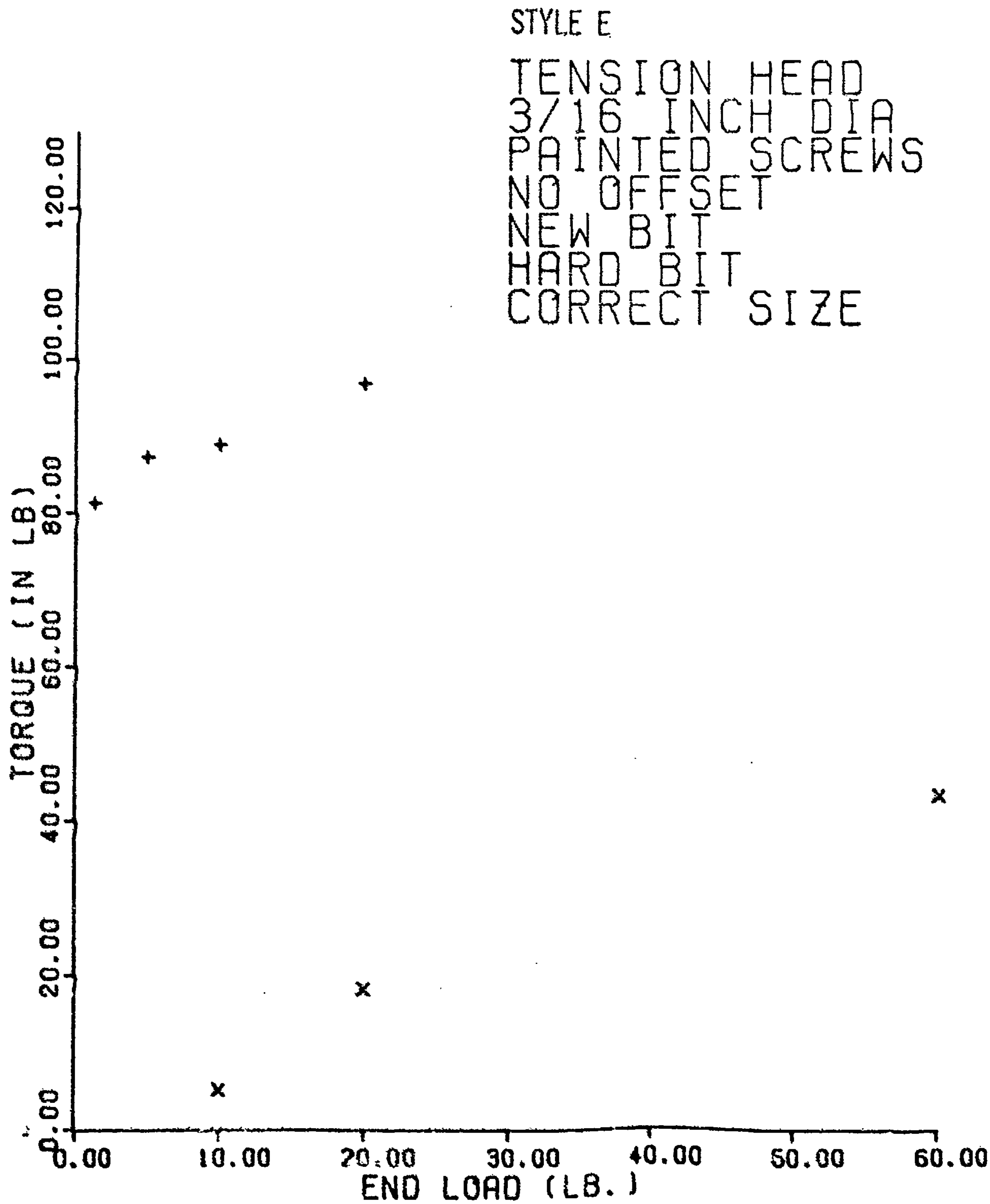

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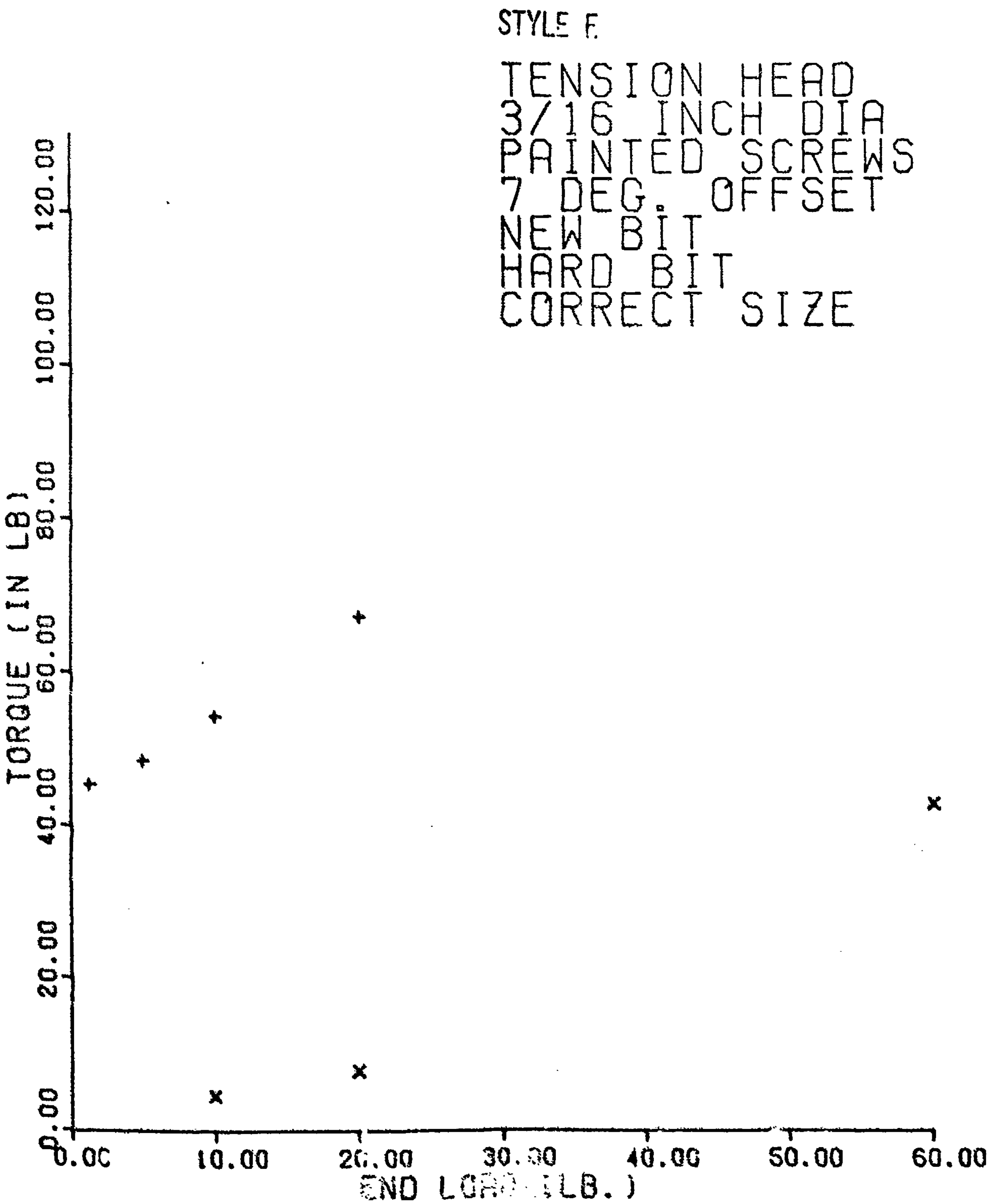

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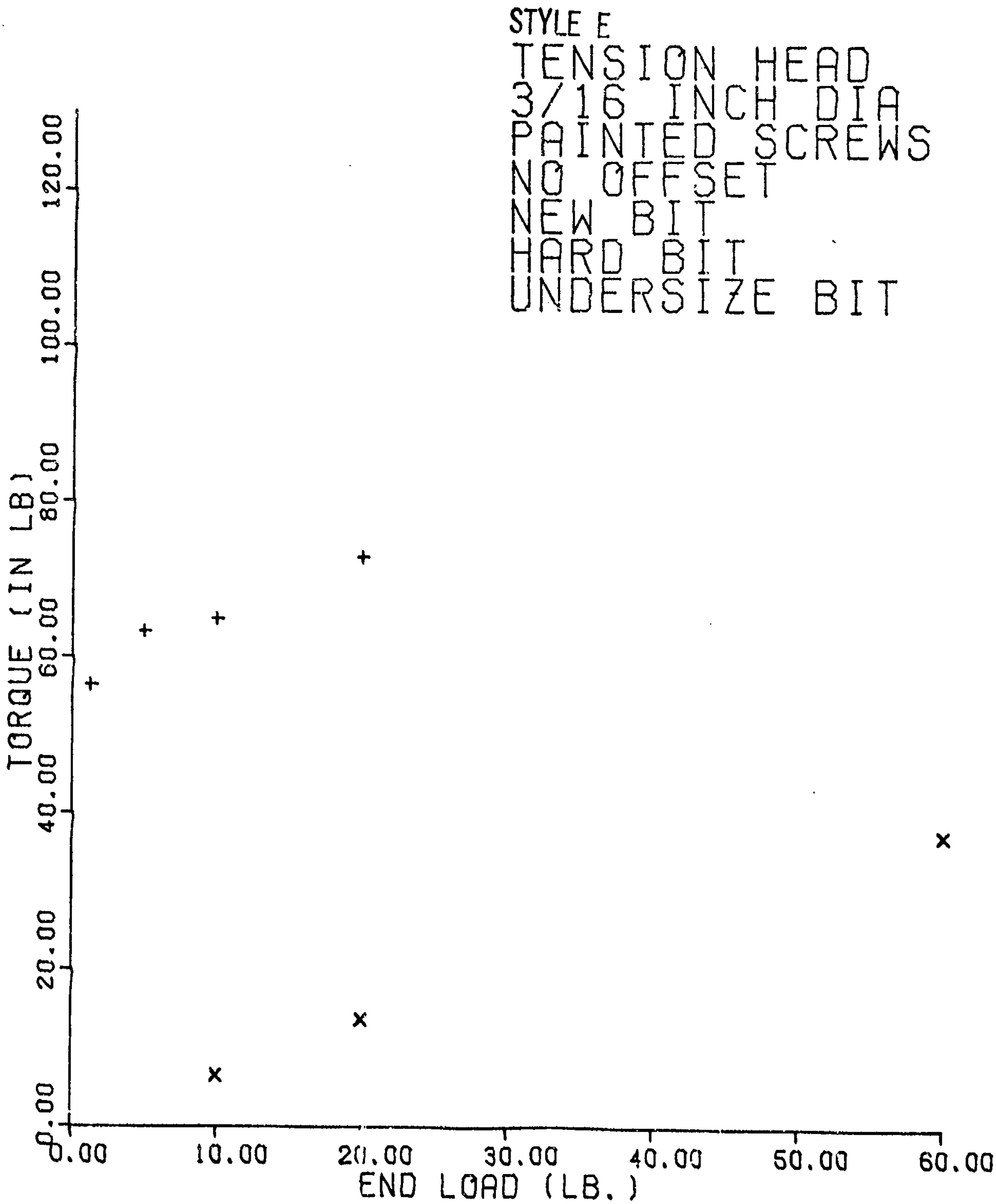

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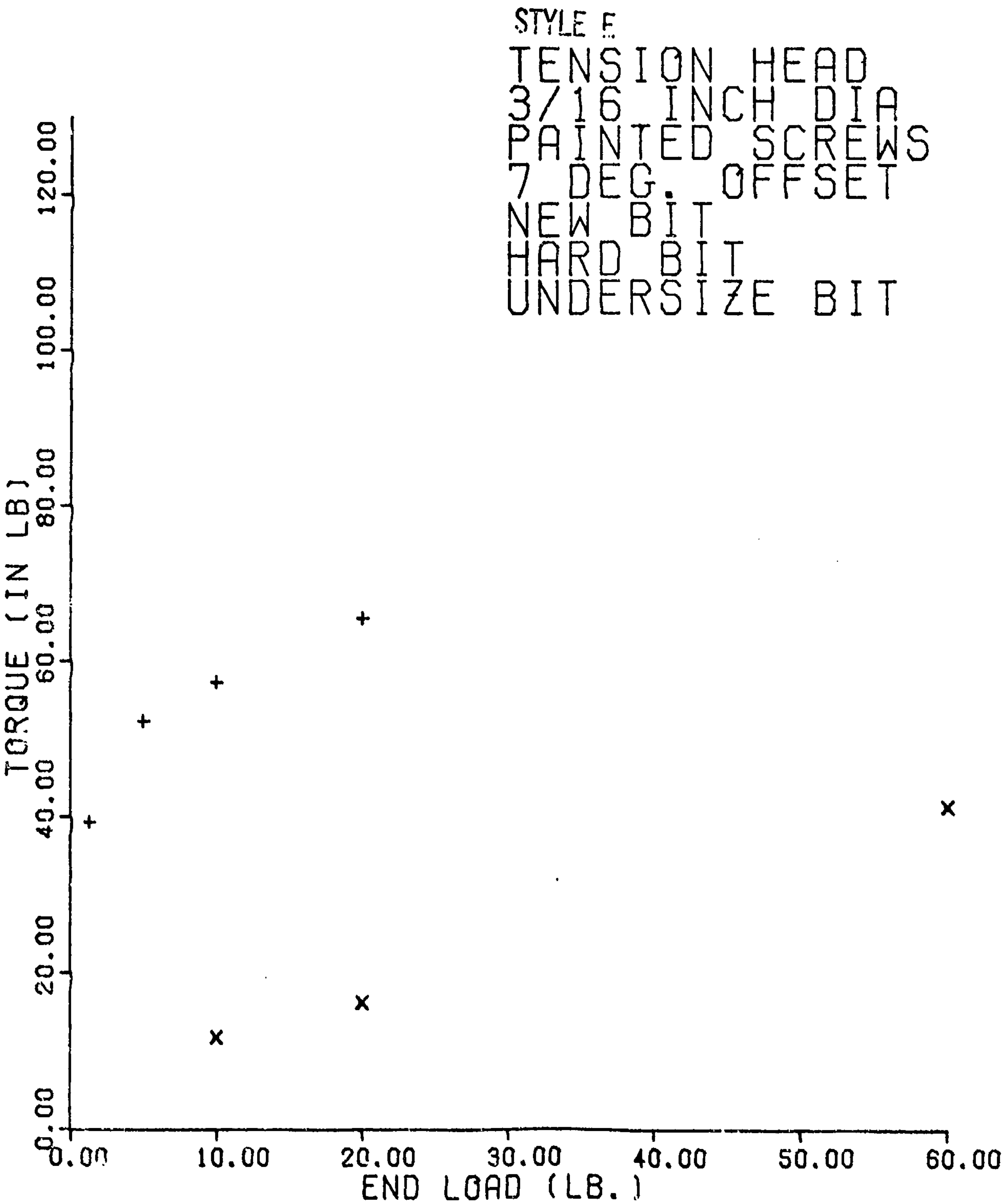

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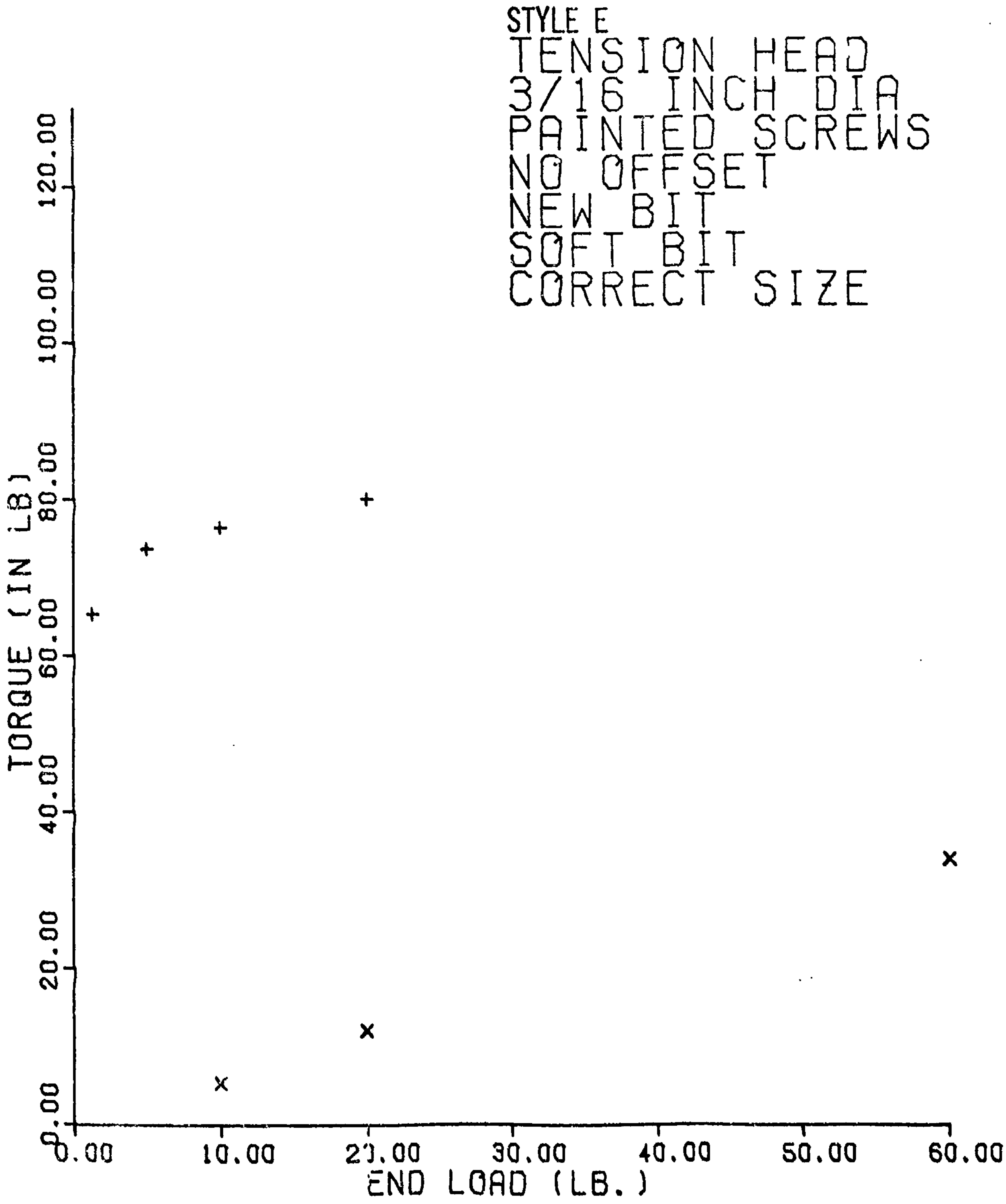

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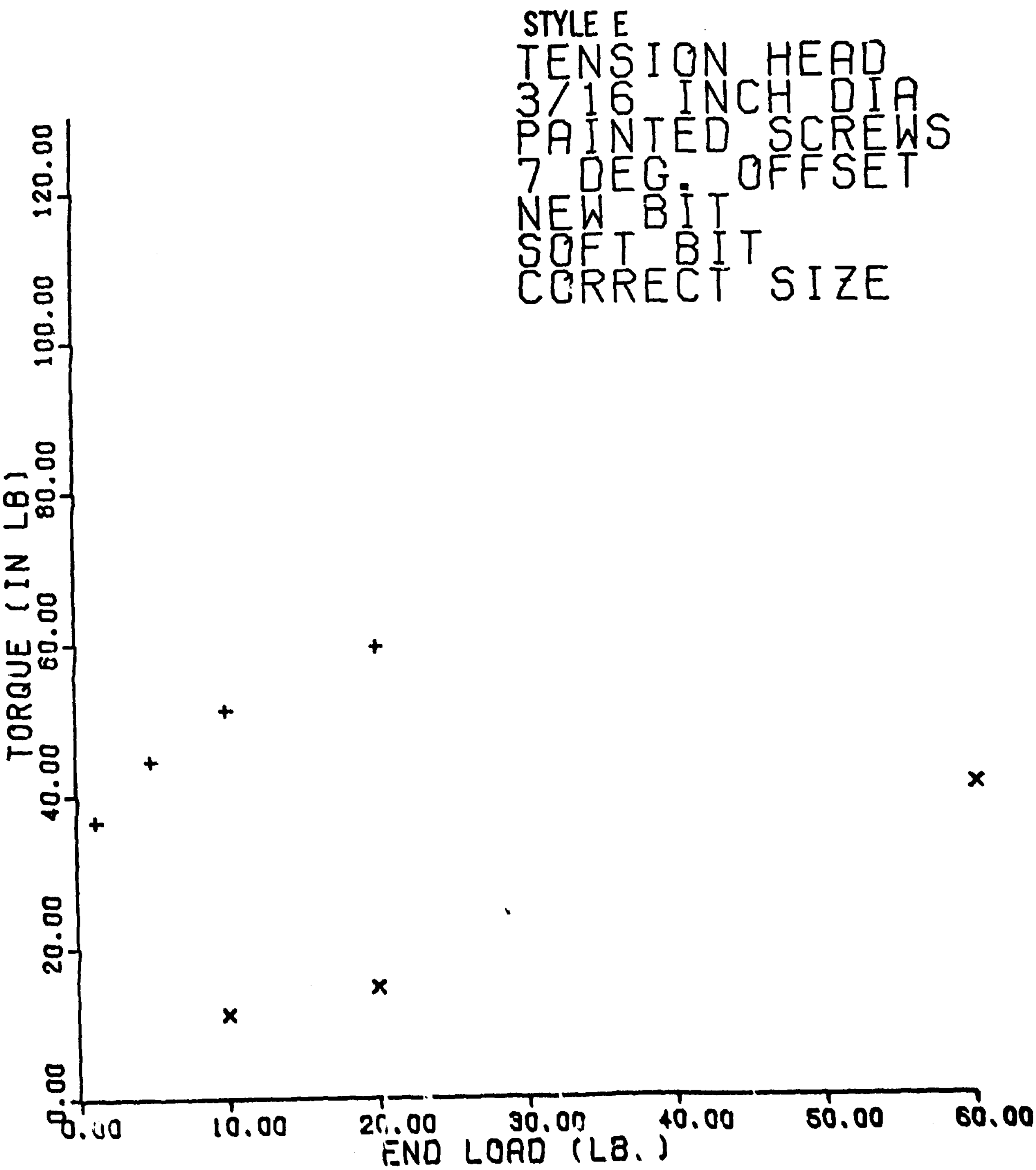


Figure 68. Style E Test Results

End Load

Table 3 lists the torque values attained at the various end loads for the first failure..

TABLE 3

FIRST FAILURE END LOAD AFFECT ON TORQUE

Fastener Recess Styles

	A	B	C	D	E
End Load, Lbs	Torque, In-Lbs.	Torque, In-Lbs.	Torque, In-Lbs.	Torque, In-Lbs.	Torque In-Lbs.
1.3	93.5	102.7	122.0	75.3	106.0
5.0	94.0	103.7	123.3	81.7	112.3
10.0	98.5	102.7	121.3	88.3	113.0
20.0	100	103.7	124.7	93.3	117.7

Each test data point was obtained by testing three or four replicates.

The procedure for obtaining the four replicates for the second failure determination was done in the following manner. For the 1.3 lb end load case, one screw of the four was taken from the initial failure 1.3 end load case; the second screw was taken from the initial failure 5 lb end load case; the third screw was taken from the initial failure 10 lb end load case; and the fourth screw was taken from the initial failure 20 lb end load case. A similar procedure was followed in obtaining the four replicates for the 5 lb end load case. This procedure was repeated for each end load and each test condition.

The table values are the torque values obtained under the most favorable conditions (no paint, no off-set, and new, hard bits of the correct size). The values are averages of the repeats for each test condition.

Table 4 lists the torque values attained for the second failure.

TABLE 4

SECOND FAILURE END LOAD AFFECT ON TORQUE

Fastener Recess Styles

	A	B	C	D	E
End Load, Lbs.	Torque In-Lbs.	Torque, In-Lbs.*	Torque, In-Lbs.	Torque, In-Lbs.	Torque, In-Lbs.
10	40	0	29	3	5
20	51	0	42	5	12
40	68	0	-	-	-
60	72	0	78	17	39

* Bits broke on first failure

It can be seen from a comparison of the initial failure torque values that a correlation exists between torque and end load for four of the five recesses tested. For new fasteners and bits, end load helps achieve higher torque levels. The lack of dependence for Style B is a direct result of the recess design. Style B was designed to be "independent of end load". As can be seen from the second failure torque values, the correlation of torque and end load very definitely increases with failed screws. For Style A, the torque capability almost doubled when the end load was increased from 10 to 60 lbs;and with Style C it more than doubled.

It can be observed from the various plots of torque vs end load that the end load dependency remains when the bit is off-set or undersized, with the screws painted, etc. It was also observed that the greatest data scatter occured at 1.3 lb end load. This is probably due to the inherent difficulty of maintaining and duplicating test conditions under the dynamic conditions of torque application.

Paint

As expected, paint in the recess did have a measurable effect on the obtainable torque for four of the five major recesses tested. Baseline torque values of the first and second failures are compared with the values for painted screws in Table 5 below.

TABLE 5

PAINTED SCREW TEST RESULTS

Fastener Recess Styles

		A	B	C	D	E
No Paint	1st	96.5	103.0	122.8	84.7	112.3
	2nd	54.7	0*	49.5	8.0	18.5
With Paint	1st	75.3	104.8	108.8	68.3	88.7
	2nd	53.3	0*	27.3	8.2	22.4
Δ First Failure		-22%	+2%	-11%	-18%	-21%

* Bits broke on first failure

The table values are overall averages of data taken at four end loads (1.3, 4, 10, and 20 lbs) and with new, hard bits of the correct size, and angle. The change in available torque (first failure) varied from a slight gain attributed to data scatter for Style B to a loss of 21% for Style E and and 22% for Style A.

With the exception of Style C, paint does not appear to have much of an effect on the second failure torques. Why Style C is different from the others in this case is not consistent with the painted, 7° angle test condition.

The data in Table 6 for the painted, 7° off angle case show that Style C demonstrated the highest torque levels of any style. (Notice, however, that this is approximately 50% of the torque available under "ideal" conditions.) As the degree of damage to the recess determines its second torque levels, the paint in the recess may have reduced the effectiveness of the design in allowing the bit to back out of the recess before inflicting relatively heavy damage. With the bit at an off angle to start, the bit was already in effect backing out at the start of the test. Hence, little damage and a greater second failure torque capability.

Off Angle

TABLE 6

OFF-ANGLE TEST RESULTS

Fastener Recess Style

		A	B	C	D	E
0° Angle	1st	96.5	103.0	122.8	84.7	112.3
	2nd	54.7	0*	49.5	8.0	18.5
7° Angle	1st	68.3	99.4	82.3	66.0	69.3
	2nd	17.5	37.8	30.4	19.8	22.9
Δ First Failure		-29%	-3%	-33%	-22%	-38%

* Bits broke on first failure

As can be seen from the values in Table 6, the seven degree off-set angle significantly degrades the torque capability of the recess and bit combination in four of the five recesses for the first failure. All had significant degradations at the second failure.

It is interesting to note that the seven degree off-set changed the failure mode for Style B from the bit to the recess. Also, the resultant torque capability of the second failure showed a significant decrease.

Soft Bits

The test results confirmed the Air Force general experience that soft bits are detrimental to the torque generating ability of the recess/bit combination. The degradation was highly dependent on the particular design. One problem that was not duplicated in the laboratory is the rapid wear that is suffered by the soft bits which in turn results in reduced torque capability. (See sections on worn bits.)

The Style A and Style B bits, which have relatively fine points compared to the other bits tested, failed by plastic deformation or fracture and therefore produced no torque for the second failure attempt. There was some plastic deformation but no serious damage (such as breakage) of the other bits. Overall, the soft bits gave the poorest second failure capability. (See Table 7.)

TABLE 7

SOFT BIT TEST RESULTS

Fastener Recess Style

		A	B	C	D	E
Hard Bits	1st	96.5	103.0	122.8	84.7	112.3
	2nd	54.7*	0*	49.5	8.0	18.5
Soft Bits	1st	61.9	67.3	76.2	78.5	90.5
	2nd	0	0	27.0	9.8	12.5
First Failure		-36%	-35%	-38%	-7%	-19%

*Bits broke on first failure

Undersize Bits

TABLE 8

UNDERSIZE BIT TEST RESULTS

Fastener Recess Style

		A	B	C	D	E
Correct Bit	1st	96.5	103.0	122.8	84.7	112.3
	2nd	54.7	0*	49.5	8.0	18.5
Undersize Bit	1st	58.8	56.7	95.4	55.9	72.9
	2nd	30.1	8.8	39.7	13.8	25.3
First Failure		-39%	-45%	-22%	-34%	-35%

*Bits broke on first failure

As expected, this turned out to be a severe test. The observation of the field team was that undersize bits are being used by inexperienced mechanics because the numbering system of the bits and recesses is confusing. Even experienced mechanics used them when the proper size was not handy. (NOTF: Not only is the numbering system confusing, the names of the recesses were being confused and worse yet, some recesses were thought to require higher torque than others.)

As can be seen from the table, torque capability was reduced from 45 to 22% with the undersized bits for the first failure. Even lower values were obtained for the second failure.

Worn Bits

The wear obtained with the tumbling procedure was, as expected, very uniform. However, distinct differences were noted between this wear and actual field wear. First of all there was, of course, no plastic deformation in the artificially worn bits. Certain types of bits are subject to yielding and plastic deformation and this appears to be a very significant mechanism in reducing the torque capability of the bit/recess combination. The flush contact between the recess wall and the bit faces or flutes is lost and a force component is generated that counteracts the applied end load and may even allow the bit to slip out of the recess. The edge of the recess would also be expected to yield or plastically deform. (See Figure 69.)

The tumbling action did not simulate this damage; it does simulate the rounding of the outward facing edges but in this case with a greater radius than field wear. (This radius probably depends on the size of the tumbling media which in this case was relatively large.) The rounding of these outward facing edges in the field appears to be caused more by plastic deformation of the flute faces rather than by wear.

Because of these deficiencies, the data from the worn bit test conditions is not reported.

Torque

One result inherent in all of the testing is that the recess and/or bit is damaged when excessive torque is applied. This thought is implicit in the "damage tolerance" characteristic of the results when comparing first and second failure results. It was also observed that end load affects the torque levels. That is, higher end loads will result in higher torque levels. But with higher end loads forcing the bit to stay in contact with the recess longer and at higher stresses, one would also expect that high end loads would also be associated with greater damage being imparted to the recesses and/or bits.

The data confirms this hypothesis; high end loads contribute to greater damage to the recesses and/or bits. The pictures in Figure 70 are for a 1.3 lb end load and the pictures in Figure 71 are for a 20 lb end load condition.

Figure 69. Field Worn Bit. Note new bit on left side

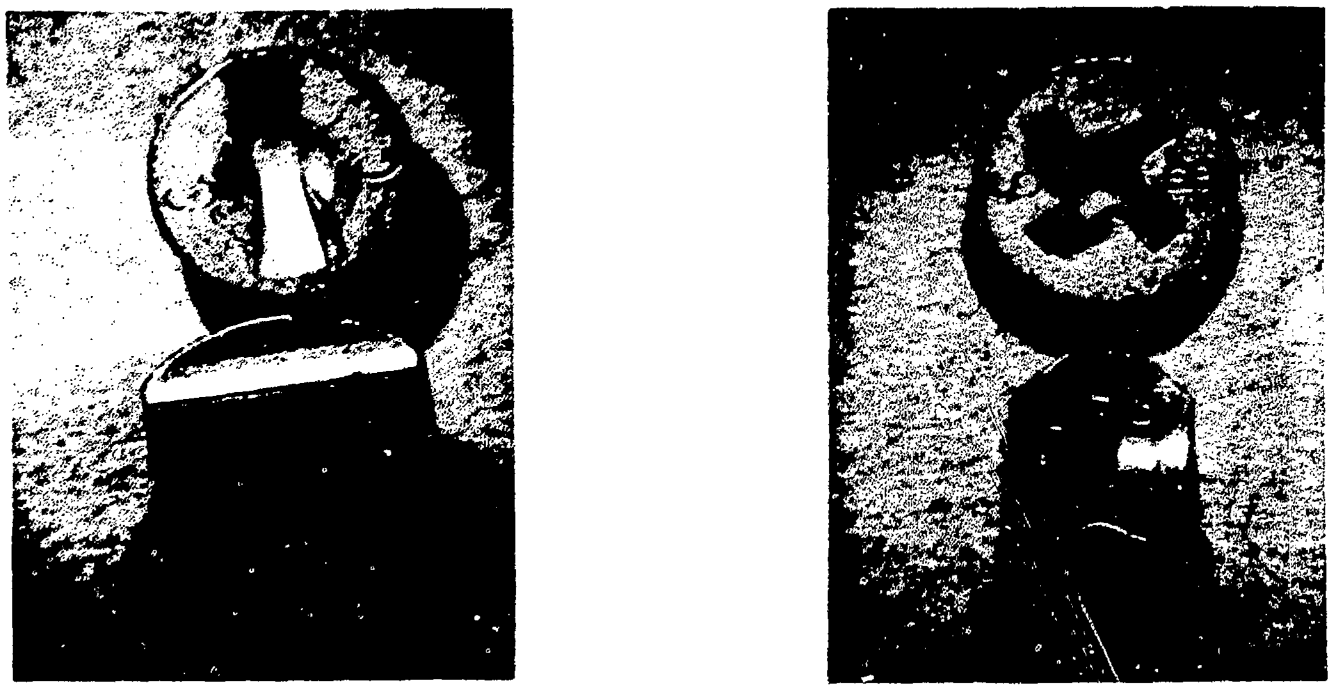


Figure 70. 1.3 Lb End Load Failure

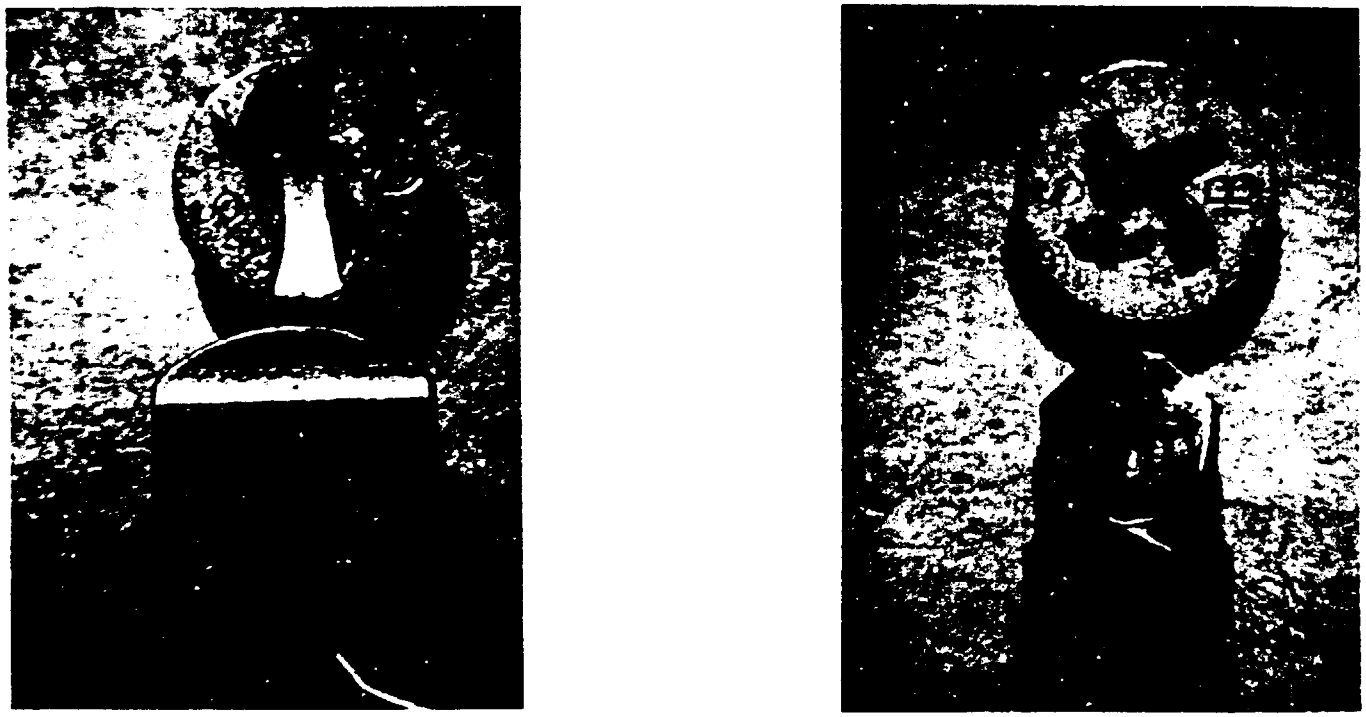


Figure 71. 20 lb End Load Failure

The recess tested at 20 lb end load shows greater damage than the one at 1.3 lb end load. We can also observe this from the data. If the 20 lb end load condition allowed greater damage, then the second torque levels would be lower for these fasteners than the initial 1.3 lb end load condition. Table 9 summarizes this data.

Style A design features are such as to encourage the bit to back out because of the slope of the recess. Because of this, the values for torque are relatively close, though the lower end load initial test condition does have higher torque.

Style B design is intended to be "independent" of end load. The data showed that this was true for the initial failure mode (e.g., see end load discussion) and also true for the second failure at low end load conditions. However, due to the damage inflicted on the first failure, higher end loads not only allow more damage but also produce higher torque levels for the second failure even for a design that is end load "independent".

Style C, D, and E show dramatically that the higher end loads allow more damage and as a result lower torque capabilities for the second failure.

Recess Style

The test results are summarized for the recess styles in Figures 72-74. Three test conditions are shown. One for the "perfect" condition, then painted, and last painted with 7° offset bit angle.

These figures are very interesting and a number of observations can be made from them.

First, for the first failure curves, all of the recess styles lie substantially above the dashed line at 30 inch pounds, which is the recommended installation torque value. From this perspective, each one of the styles provides sufficient torque capability; and if damage were never experienced, each could be expected to give satisfactory service. This leads to two thoughts. One is that this verifies the deficiency in present testing approaches that concentrate on the "first failure" torque capabilities. Damage does occur in the field. The designs must be damage tolerant and the test methods must go further that just show mint condition capabilities. Next, in relation to the recommended torque levels, all of the styles have excessive first application torque capability. As a result, overtorquing is not only possible, but it is also encouraged by the recess design.

TABLE 9

COMPARISON OF END LOAD DAMAGE EFFECTS

STYLE	INITIAL TEST END LOAD	2ND TORQUE CAPABILITIES IN LBS	
		10 LB END LOAD	60 LB END LOAD
A	1.3	13.6	35.8
	20	11.0	31.5
B	1.3	22.1	41.62
	20	22.8	33.83
C	1.3	15.54	52.23
	20	9.23	38.86
D	1.3	13.57	32.71
	20	4.43	15.21
E	1.3	11.45	50.39
	20	5.0	32.0

Figure 72.

RECESS COMPARISON

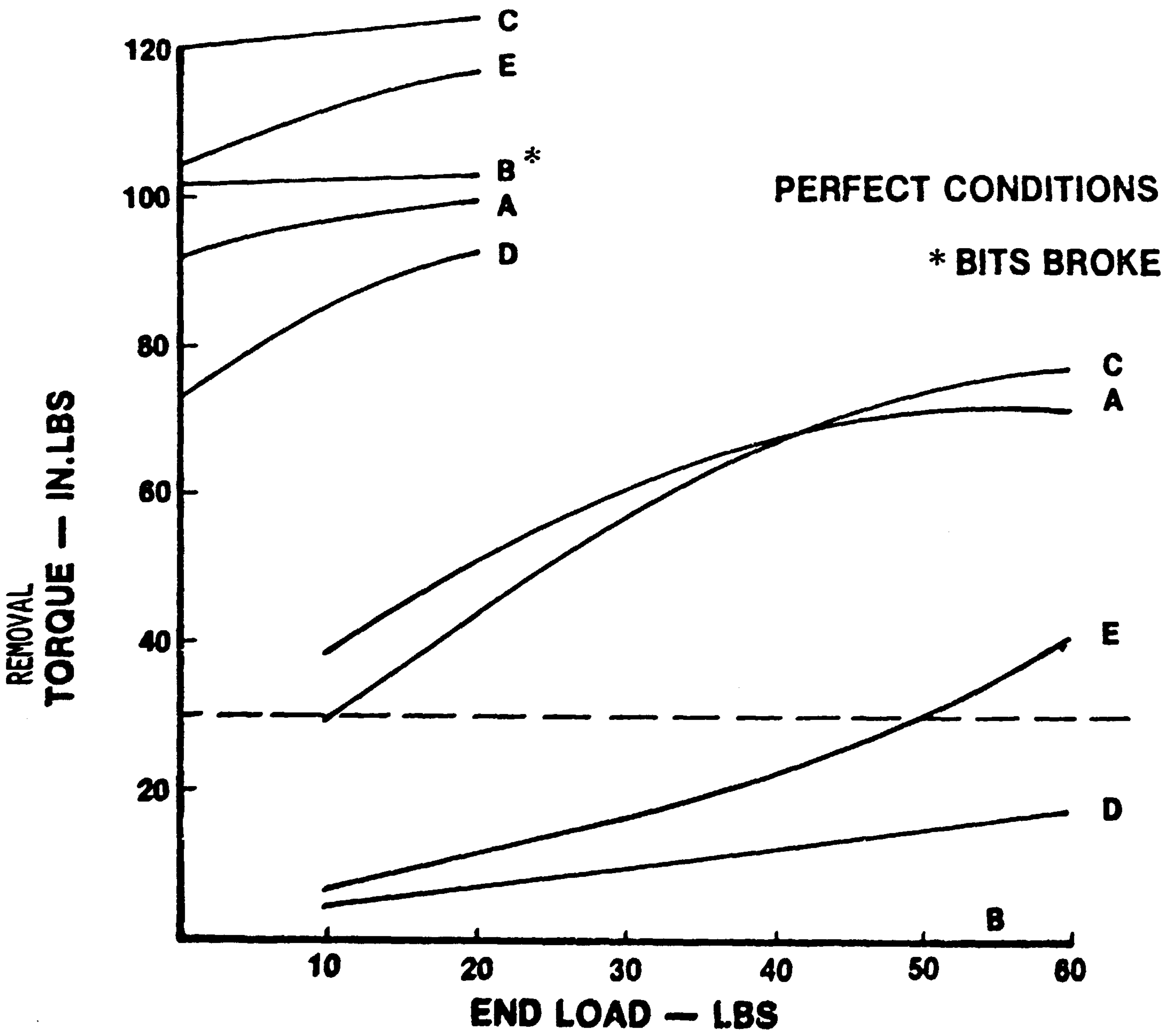


Figure 73

RECESS COMPARISON

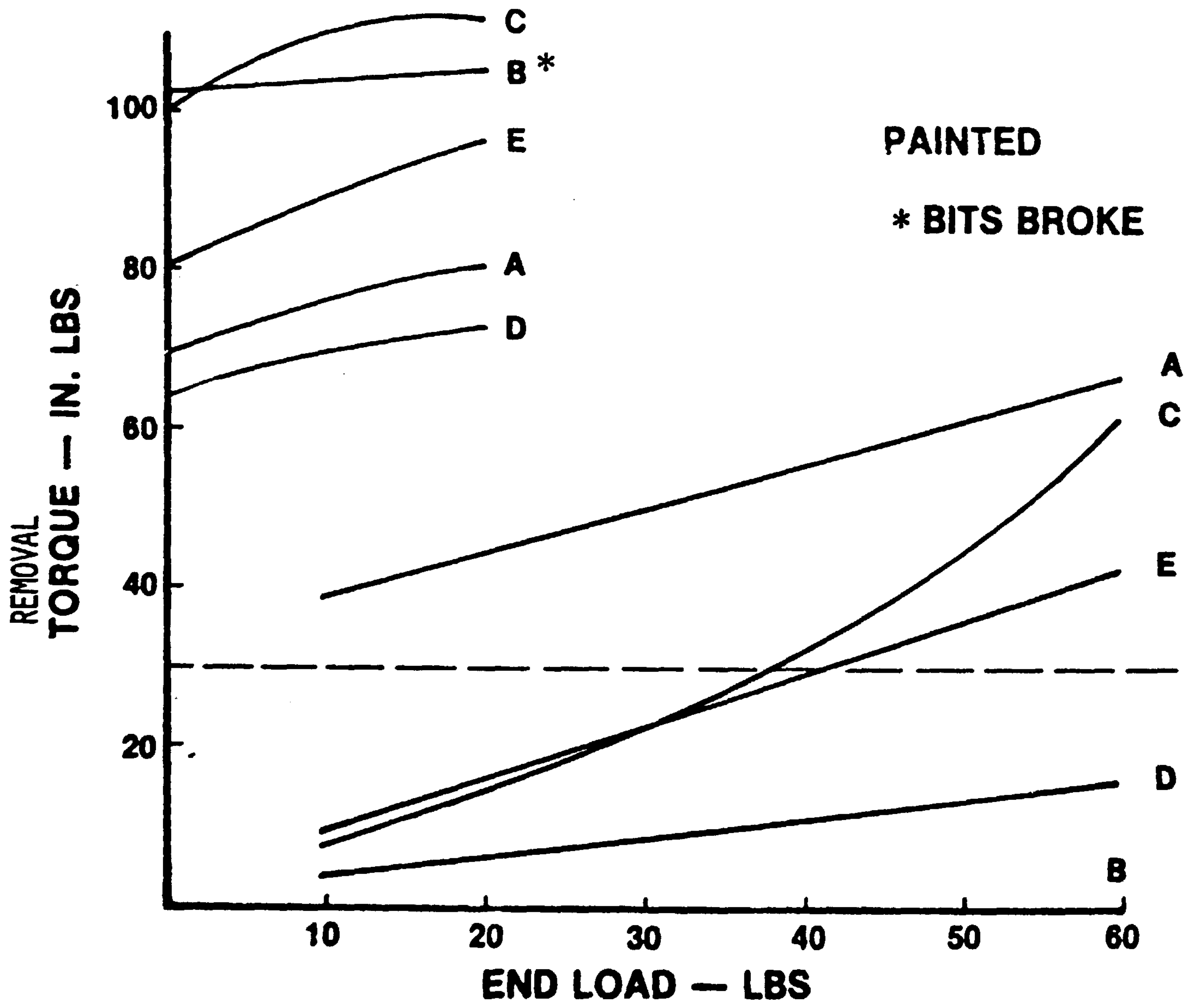
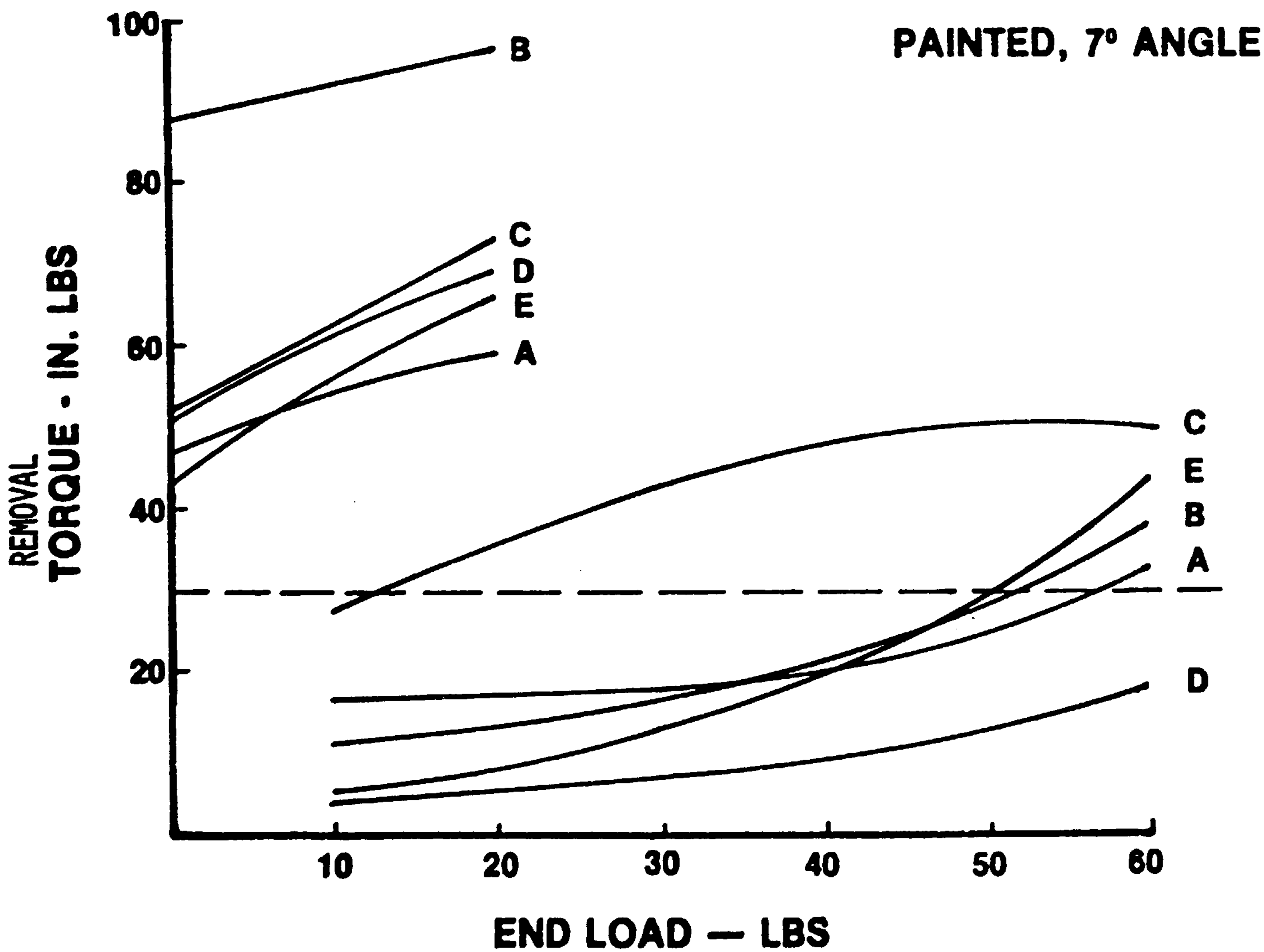


Figure 74

RECESS COMPARISON



Second, as the test conditions become more severe, the torque levels decline significantly. The typical field condition of a painted recess, off-angle driver indicates that the recess must be designed for these conditions rather than the "perfect" conditions.

Third, the performance of the recesses at the second failure is substantially lower than the initial failure. This is consistent with field experience, in that the data reflects torque abilities so low that removals would be impossible.

Recess Damage

The purpose of this section is to briefly review the modes of failure of the recesses. By studying these failure modes, one can gain insight in how to improve recess designs.

Naturally enough, the recess fails at the point of maximum stress. And every recess will always have such a place. The recess should degrade slowly and not have a disabling failure mode. Of the recesses tested, each tended to fail in a disabling way as evidenced by the low second failure characteristic curves.

First, consider the Hi-Torque, Torq-Set, and Tri-Wing recess failures as shown in Figures 75 through 77. These and subsequent figures for Torx and Phillips are for the "perfect" test conditions. Notice that these three styles have similar failure modes; i.e., "wedges" have been peeled back from the recess walls. The failure starts at the outer-most edge where the depth is very shallow leaving little load bearing wall area to absorb the stress. As the failure progresses, less total load bearing wall area is available due to the previous wall failure and due to the tool riding out of the recess with the wedges.

Hi-Torque, Torq-Set, and Tri-Wing have some features in common which provide this failure mode. They are relatively wide recesses extending to near the outer perimeter of the head. Because of this, the recess depth is necessarily shallow with a shallow slope because of the shape of the flush head. So the point where the torque from the tool is greatest, it is also the point where little bearing area is available resulting in high stresses.

To avoid this failure mode, the recess should be relatively deep out to the outer tip of the recess groove. This would provide a fairly uniform shape to the load bearing surface and avoid stress concentration areas. This also implies that the recess not be very wide in order to achieve this depth. This should not cause any difficulty in achieving torque as all styles have approximately 100 inch pounds torque capability in the 3/16" size for the condition tested.

Figure 75 - Failed Recesses (Hi-Torque)

Figure 76 - Failed Recesses (Torq-Set)

Figure 77 - Failed Recesses (Tri-Wing)

The previous paragraph describes in part some features of the Torx and Phillips recesses. Neither of these recesses is wide compared to the other three styles and both have relatively uniform depth along the side load bearing surfaces. Their recess failures are shown in Figures 78 and 79. These recesses failed near the inner tips of the grooves where little material is available to withstand the stresses. The tip areas are flattened and/or rounded. These recesses need a way to relieve the stresses on those surfaces before damage occurs. This can be accomplished by sloping the load bearing surface to allow the tool to slide out when the forces get too high.

A recess designed to have a damage tolerant characteristic would then have the following design features:

a. Width of recess - it would be relatively small.

b. Slope of bottom surface - it would be relatively uniform and deep to the outer tip of the recess.

c. Slope of load surface - it would have a slope to allow the driver to slip out of the recess prior to inflicting damage to the surface itself.

Stock Bit and Screw Comparison

Since the fasteners and bits for the test were procured as a special order. i.e., were made from the same lot of material and received closer quality control, the question naturally came up as to how the performance of the custom-made fasteners compared to the performance of fasteners obtained "off-the-shelf".

Several tests were therefore run to compare the torque values obtained with off-the-shelf bits and screws to the values obtained in the test program. Besides stainless steel screws, titanium screws were also tested in this follow-on test. The values are tabulated in Tables 10 and 11 below:

TABLE 10

STYLE C COMPARISON FOR STOCK SCREWS

First Failure			
END LOAD LBS	CUSTOM SCREWS A286 TORQUE, IN-LBS	OFF-THE-SHELF SCREWS	
		A286 TORQUE, IN-LBS	TITANIUM TORQUE, IN-LBS
1.3	122.0	122.3	103.0
5.0	123.3	122.7	107.7
10.0	121.3	124.7	109.0
20.0	124.7	125.3	112.0

Second Failure			
10	29.3	32.2	11.0
20	41.5	33.0*	21.3
60	77.8	88.0	42.3

NOTE: First failure values are averages of three repeats; second failure values are averages of four repeats with exception of * which is an average of only two values -- with an uncharacteristically high spread, 9 and 57 inch pounds -- due to two bit failures at the first failure. The comparisons were made between tests under ideal conditions only (no angle, no paint, correct bit, etc.).

TABLE 11

STYLE D COMPARISON

	First Failure		
END LOAD LBS	CUSTOM SCREWS A286 TORQUE, IN-LBS	OFF-THE-SHELF SCREWS A286 TORQUE, IN-LBS	OFF-THE-SHELF SCREWS TITANIUM TORQUE, IN-LBS
1.3	75.3	78.0	66.7
5.0	81.7	86.7	74.3
10.0	88.3	89.3	85.0
20.0	93.3	91.3	82.3
	Second Failure		
10	2.5	9.5	6.5
20	4.8	17.5	7.3
60	16.8	27	22.5

For the first failure, the torque values obtained were basically the same for the stainless steel screws and the titanium screws produced torque values of 11 and 13 percent less than the steel screws.

In order to verify the results of the A286 vs titanium fasteners, yield values were determined for each material. It was felt that the yield values would as a first approximation explain recess performance from a material point of view. The yield values for the stock fasteners areas follows: A286, 3660 pounds and titanium, 3518 pounds. As the titanium has a lower yield strength, one would expect the titanium fasteners to also exhibit lower torque values. This was confirmed by the data given in the tables above.

These results lead us to the expectation that the data obtained without controlled material fasteners has yielded results which are typical of stock fasteners and bits.

Figure 78 - Failed Recesses (Torx)

Figure 79 - Failed Recesses (Phillips)

SECTION III

DETERMINATION OF REMOVAL-INSTALLATION TORQUE RATIO

Experience tells us that in a percentage of cases, the recess fails and screws cannot be removed. In those cases, the removal torque required exceeds that which the recess/bit can produce. The removal torque is affected by many parameters. Some of these are: (a) high installation torque; (b) introduction of shear loads into the fastener by the relative motion of the mated parts in service usage; (c) threads galling or "freezing" in the nuts due to material incompatibility or failures; (d) sealant in the threads acting as a wedge increasing friction; and (e) corrosion.

In order to understand the effect some of these parameters have on the removal torque, a series of tests were conducted. The purpose of the tests was to determine the removal installation torque ratio and the affect on this ratio of various parameters.

1. Materials and Specimens

The joint material utilized for this portion of the project was 2024-T3 bare aluminum alloy sheet and plate. This material was used in the as-received condition and subsequently sheared to specimen dimensions depicted in Figure 80. After shearing to the proper dimensions, the pieces of material were placed in a drill fixture and the fastener holes fabricated. Hole dimensions are given in Table 12. The use of hole dimensions given in Table 12 in conjunction with the use of standard recess fasteners leads to a clearance fit of over 0.010 inches between the fastener shank and the hole it is installed in. This condition is typical for panel type removable fasteners.

The recess fasteners utilized in the test program were configured per NAS Standard 1580, "Bolt, 100° Flush, Tension Head" which is a commonly accepted standard recess fastener for aerospace use. However, two different fastener materials were used in conjunction with two different recess styles. The fastener materials were A286 CRES (Stainless Steel) with a minimum tensile strength of 160 KSI and a carbon alloy steel also having a minimum tensile strength of 160 KSI. The finish on the A286 fasteners was bare (no plating) but these fasteners were passivated per Federal Specification QQ-P-35. The alloy steel fasteners were cadmium plated per Federal Specification QQ-P-416, Type II. The A286 fasteners contained a hexagonal (Allen Wrench) wrenching recess conforming to ANSI Standard B18.3 and NAS333. The alloy steel, cadmium plated fasteners, had an internal wrenching recess conforming to Military Standard MS33750 (Hi Torque). The nuts were all cadmium plated alloy steel.

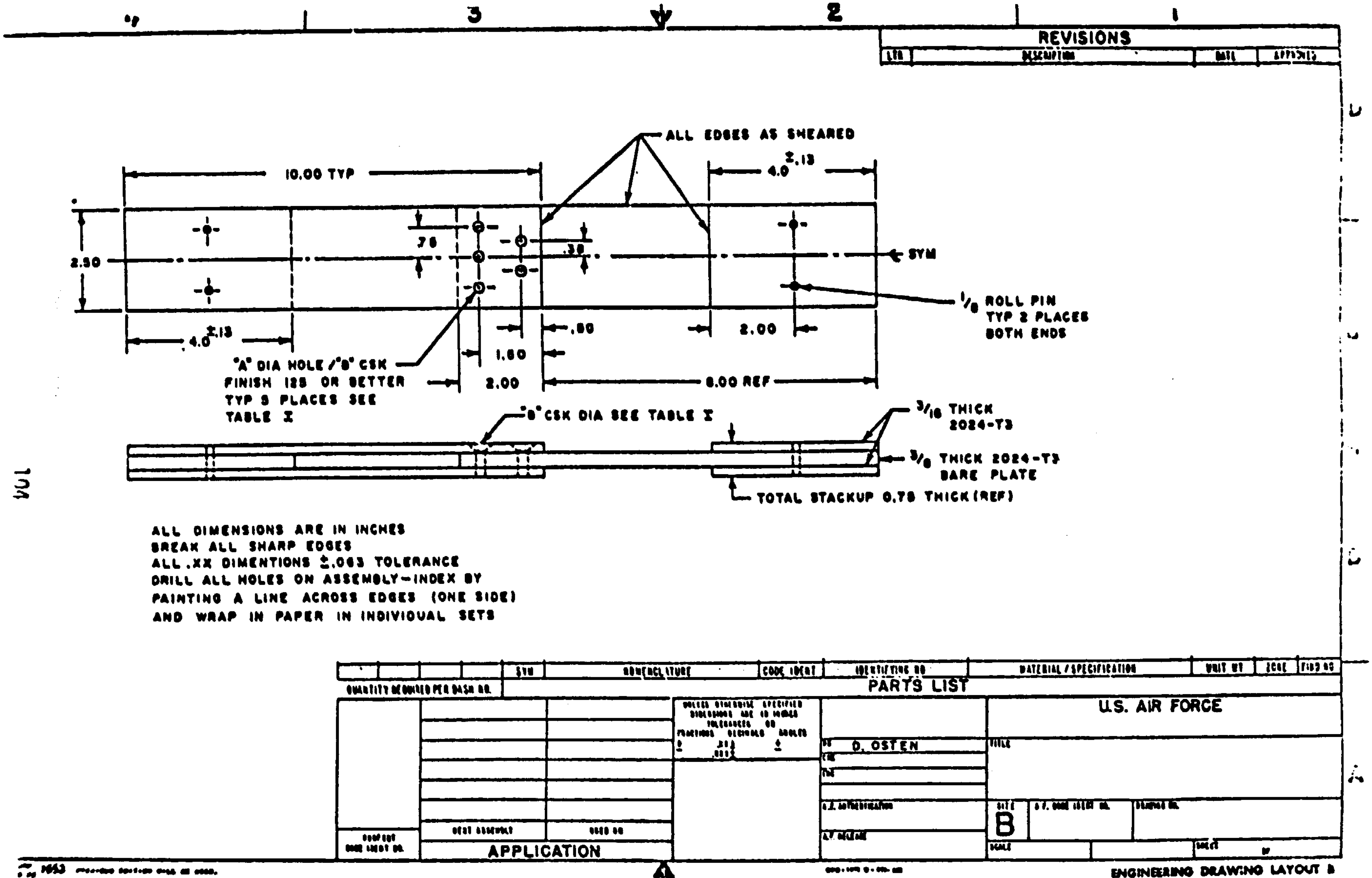
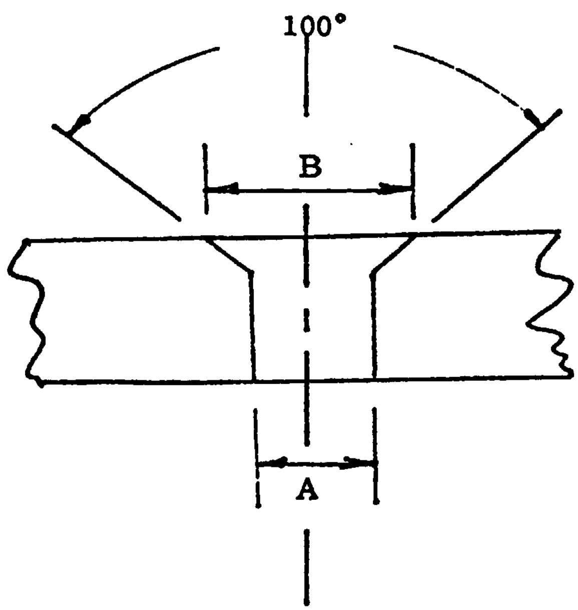


Figure 80. Joint Specimen Specification Drawing

TABLE 12 - HOLE DIMENSIONS FOR JOINT SPECIMENS

Specimen Identification	Nominal Hole Diameter In.	"A" Hole Dia Dimension In.	"B" CSK Dimension 100° Angle X Given Dia In.	Remarks
1 thru 19	1/4	.2500 + .0022 - .000	.493 .503	
20 thru 30 & 49	3/16	.1910 + .0022 - .000	.372 .382	
31 thru 41	5/16	.3120 + .0022 - .000	.623 .633	



A portion of the fasteners tested were installed in the joint specimens being "wet with sealant". The sealant used was MIL-S-8802 Fuel Tank Sealant. This sealant was applied only to the fastener with no sealant applied to the mating nut or faying surface of the joint.

Two levels of installation torque were used during the assembly of the fasteners into the joint specimens. The lower torque value was taken (for each appropriate size fastener) from NAS Standard 1737, "Installation Torque Limits for 160 KSI Threaded Fastener Systems Subjected to Periodic Removal". The higher torque value used was a 1.5 multiple of the NAS1737 values. For the convenience of the reader, the torque values used are as follows:

Fastener Diameter	NAS1737 Torque	(1.5) X NAS1737
3/16 nominal fastener	35 in-lbs	53 in-lbs
1/4 nominal fastener	90 in-lbs	135 in-lbs
5/16 nominal fastener	180 in-lbs	270 in-lbs

From the previous description of materials and fastener configurations used in the fabrication of test specimens, the following eight different joint configurations emerge.

- A286 Fastener
  - with sealant
    - lower install torque
    - higher install torque
  - no sealant
    - lower install torque
    - higher install torque
- Alloy Steel Fastener Cad Plated
  - with sealant
    - lower install torque
    - higher install torque
  - no sealant
    - lower install torque
    - higher install torque

2. <u>Test Procedures</u>

The sequence of operations taking place after joint specimen constructions were as follows:

a. Each of the eight specimen groups, defined previously, were divided into three test batches containing specimens from each of the eight specimen groups.

b. One test batch was allowed to remain in storage, on the shelf, at room temperature in ambient air. After 30 days in storage, each of the five fasteners in each test specimen joint was loosened and the maximum "break away" torque recorded. After initial loosening, each fastener was retightened and the installation torque re-recorded. After tightening, these specimens were subjected to a dynamic loading exposure accomplished in a servo-hydraulic fatigue test machine. After dynamic cycling, all fasteners were again loosened and the maximum "break away" torque recorded. After torque measurement, the batch one specimens were set aside and no further testing was done.

c. The second test batch of joint specimens were not stored but directly subjected to dynamic loading in the same fatigue test machine as the batch one specimens. After dynamic loading, the batch two specimens were placed in a salt fog exposure chamber and continuously exposed for fifty hours. After the fifty hour exposure, each fastener was loosened and the maximum "break away" torque recorded. These batch two specimens were then set asied for visual examination at some later date.

d. The third test batch of joint specimens were directly subjected to dynamic loading identical to batches one and two. After dynamic loading, batch three specimens were placed in a salt fog exposure chamber for 150 hours. After the 150 hour exposure, each fastener was loosened and maximum "break away" torque recorded. Specimens were then set aside for future visual examination.

In the dynamic loading sequence, each specimen joint received 400 cycles of constant amplitude tension-tension loading. The minimum load in all cases was ten percent of the maximum load (R = 0.1). The maximum load for each joint specimen was a variable depending on the size fastener installed. This maximum load was calculated as follows. From MIL-HDBK-5, "Metallic Materials and Elements for Aerospace Vehicle Structures", Table 8.1.5.2(a) lists the maximum load per fastener for alloy steel, flush head fasteners installed in the appropriate thickness 2024-T3 bare aluminum alloy joint for which a certain permanent deflection takes place (yield value) and a maximum load per fastener for which catastrophic failure of the joint takes place (ultimate strength). From MIL-HDBK-5, for 2024-T3 bare plate of 3/16 inch stock thickness, the following "yield" values were taken:

3/16 diameter fastener	(1,600 lbs/fastener)
1/4 diameter fastener	(2,400 lbs/fastener)
5/16 diameter fastener	(2,700 lbs/fastener)

Thus, there were five fasteners installed in each test specimen joint:

> 8000 lbs maximum load, 800 lbs minimum load for 3/16 diameter fasteners
>
> 12000 lbs maximum load, 1200 lbs minimum load for 1/4 diameter fasteners
>
> 13500 lbs maximum load, 1350 lbs minimum load for 5/16 diameter fasteners

All dynamic loading took place in ambient air and at room temperature. All specimens received 400 cycles of loading. The loading frequency was 5 Hz to 10 Hz. At no time was any fastener tightened during the dynamic loading exposure. A typical dynamic loading setup in the appropriate fatigue test machine is shown in Figure 81.

Specimens scheduled for corrosion exposure were installed in the salt fog test chamber following dynamic testing. Cabinet dimensions, exposure temperatures, contaminant composition, circulation rate, etc., are per ASTM-B-117, "Salt Fog Test". Test specimens upon removal from the salt fog cabinet were wrapped individually in paper covering without removing/scraping/brushing away any corrosion products.

After the test specimen joint had undergone the appropriate loading or loading/corrosion treatment, it was taken to a special setup for measurement of "break away" loosening torque. This setup consisted of a GSE Model 1200 electronic hand operated digital torque wrench which has a "built in" calibration capability in conjunction with a universal (static loading) test machine. The universal machine was used to "push down" on the torque wrench providing a constant uniform "end load" on the driver bit applying the removal or "break away" torque. A typical setup for the described operation is given in Figure 82. The end load or insertion forces exerted by the torque wrench were as follows:

> for 3/16 diameter fasteners, end load equalled 70 lbs.
> for 1/4 diameter fasteners, end load equalled 100 lbs.
> for 5/16 diameter fasteners, end load equalled 120 lbs.

Note: with maximum compressive load on the torque wrench, no torque reading appeared on the wrench when turning the wrench on a flat plate. However, lubricant was used between the upper platen of the universal test machine and portion of the torque wrench which was in contact with the platen.

Figure 81 - Joint Specimen Installed in Fatigue Machine for Dynamic Loading (400 cycles)

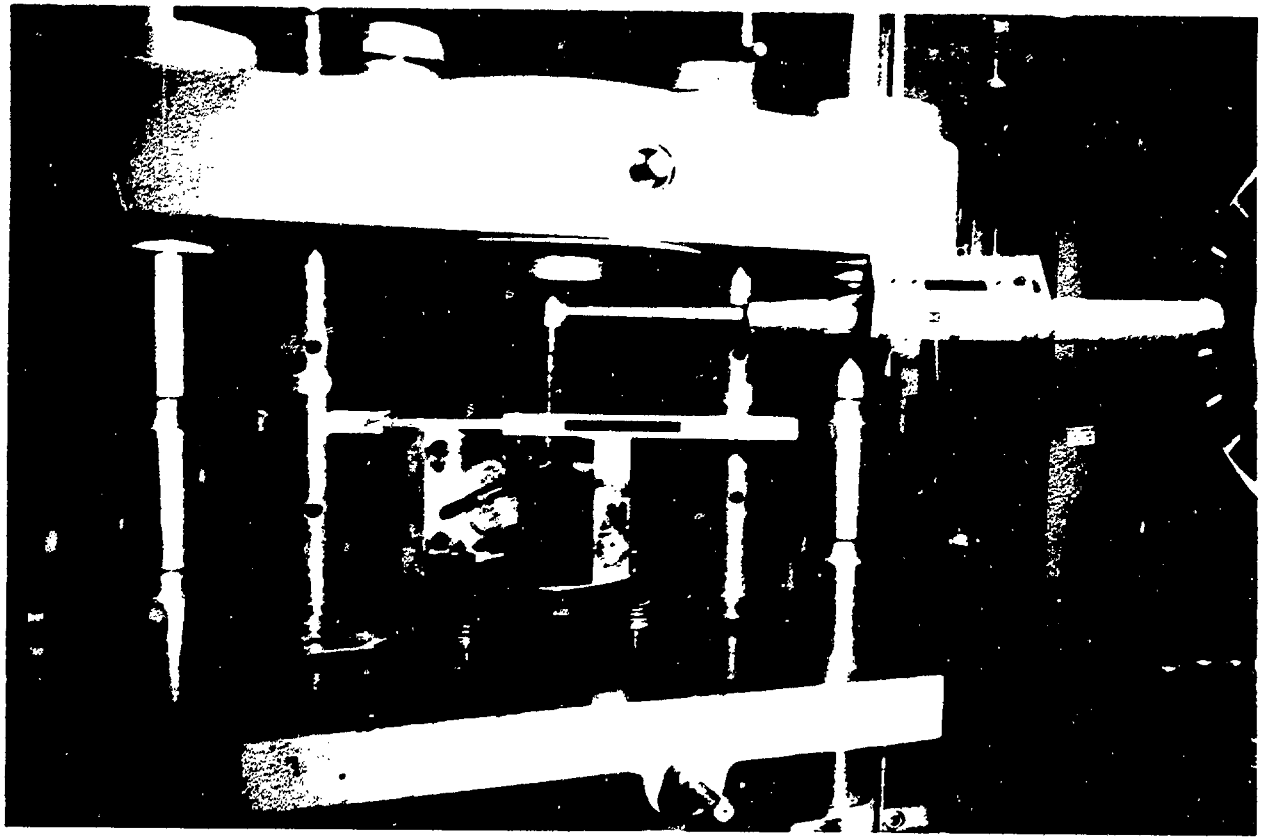


Figure 82 - Measurement of Removal Torque Utilizing Universal Test Machine and Electronic Digital Torque Wrench

3. Test Results

The test results are summarized in Table 13. For each of the five fasteners installed in each joint specimen evaluated, individual removal-installation torque values were computed and then the arithmetic mean for all data points for each joint specimen was determined. The mean value, calculated for the joint configurations evaluated is the value presented in Table 13. Ratios greater than one indicate an increase over installation torque was required to loosen the fastener. Ratios less than one indicate that loosening torque was less than the installation torque.

Although a wide variation in the removal-installation torque ratio was obtained, the results do not show any consistency among the various parameters. For example, the cadmium plated alloy steel fasteners with 150 hours exposure to salt spray show the following removal-installation torque ratios.

Size	R/I
3/16	1.32
1/4	1.22
5/16	1.46

Later attempts to measure actual corrosion levels on the fasteners and joint materials did not yield useful information.

One consistency in the data is that the cadmium plated alloy steel fasteners consistently yielded higher removal-installation torque ratios than the A286 material. The nut material in all cases was cadmium plated alloy steel. This is the primary benefit of these tests.

This finding confirms what had already been previously known about the material compatibility between fastener and nuts.

TABLE 13 - REMOVAL-INSTALLATION TORQUE RATIO RESULTS

Fastener Material	Fastener Diameter Inch	Install Torque In-Lbs	REMOVAL TORQUE/INSTALLATION TORQUE RATIO					
			No Corrosion Exposure △		50 Hour Salt Fog		150 Hour Salt Fog	
			No Dynamic Cycling	Yes Dynamic Cycling	With Sealant	No Sealant	With Sealant	No Sealant
A286	3/16	35	0.90	0.82	1.20	0.97	1.23	1.15
A286	3/16	53	----	----	----	----	----	1.07
A286	1/4	90	0.75	1.30	1.92	0.99	1.19	1.17
A286	5/16	180	0.76	----	0.92	0.94	1.05	1.22
A286	5/16	270	----	----	----	----	----	1.15
Alloy Steel	3/16	35	1.17	1.11	1.35	1.96	1.38	1.32
Alloy Steel	1/4	90	1.27	1.40	1.44	1.29	1.50	1.22
Alloy Steel	1/4	135	----	----	1.50	1.82	1.63	1.64
Alloy Steel	5/16	180	1.04	1.15	1.31	1.34	1.13	1.46

△ In test joints which received no salt fog exposure, all fasteners were installed "dry" without sealant

SECTION IV

ANALYSIS OF TENSION STRENGTH OF THE FASTENER AS A FUNCTION OF RECESS DEPTH

During an early analysis into the field problems associated with recess fasteners, it was noted that each size fastener, i.e., diameter, had its own size recess. This is true whether a shear or a tension head is used. It was also noted that the identification method between different style recesses (Hi-Torque, Torq-Set, Phillips, etc.) was not consistent. When the resulting confusion is coupled with the human tendency to use the tool that is most handy, the wrong size tool is often used.

The question naturally arose as to why not design the same size recess for use in more than one size fastener, thereby reducing the probability of misapplication of tools. This misapplication is responsible for significant reductions in the torque capabilities as shown by the results in Section II.

At least on the surface, the same size recess can be used in more than one size (diameter) screw. While the width and/or length of the recess could be held constant, the depth could be varied. This would permit higher torque levels to be generated in the larger sizes. This would be necessary as larger sizes are normally torqued to higher levels. How deep can the recesses go? Certainly, the deeper they are, the less tensile strength in the fastener heads and the less fatigue strength.

As a first step, a determination of the relation between recess depth and the tensile strength of the head needs to be known in order to trade torque capability vs tensile strength. Tension-tension fatigue and tension-bending fatigue characteristics are not amendable to analysis and must be determined by test.

This section describes an analytical determination of the tension strength of a fastener head as a function of recess depth.

1. Basis for Emperical Analysis

The procedure is presented in the context of an idealized recess shown in Figure 83. For all other recesses, equivalent idealized recesses will be assumed for the analysis. The diameter and depth of the recess will be assumed as primary variables. The taper of the recess can be expressed as a function of these two variables. The analysis addresses only the case of static ultimate strength of the fastener. No attempt will be made to consider fatigue or crack propagation type of failures. It is also assumed that the material of the fastener

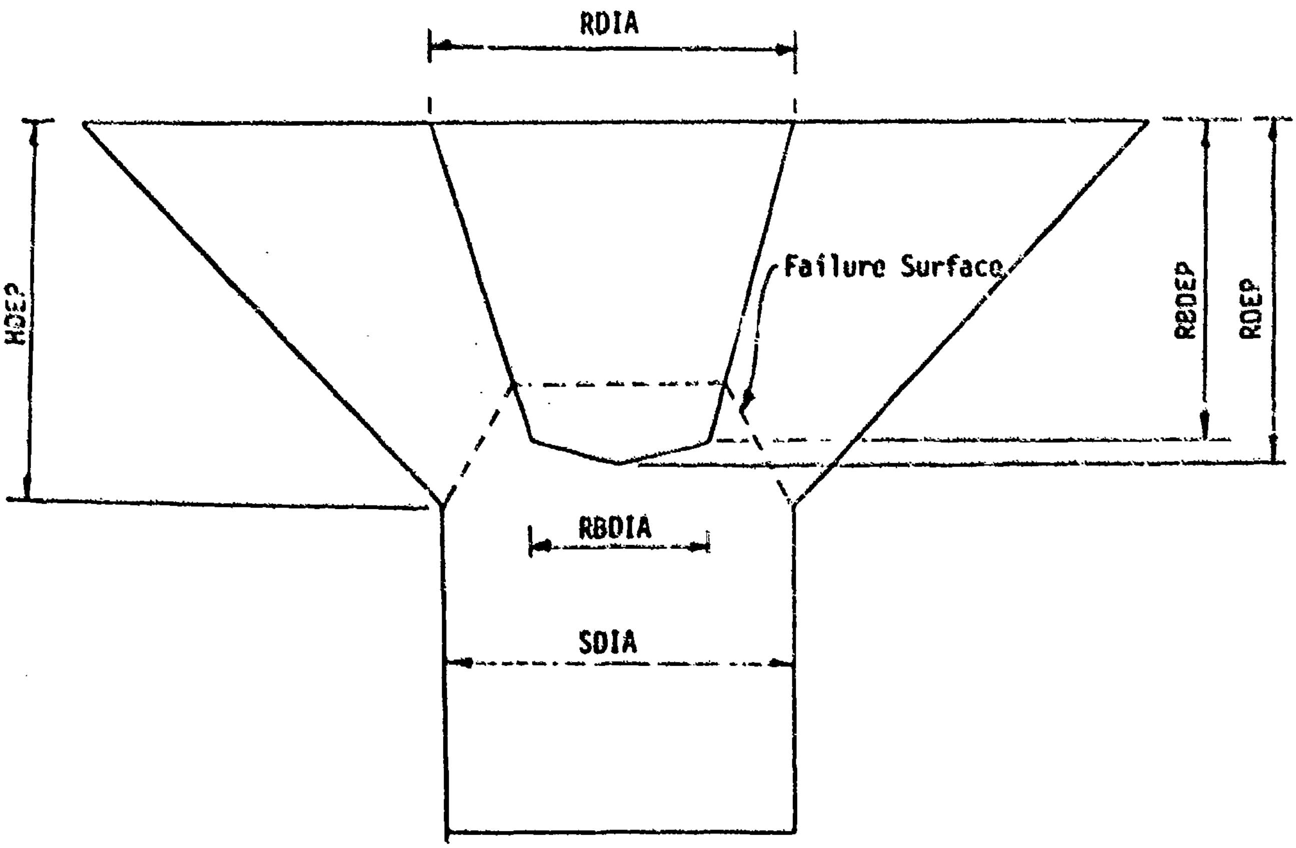


Figure 83 - Idealized Recess

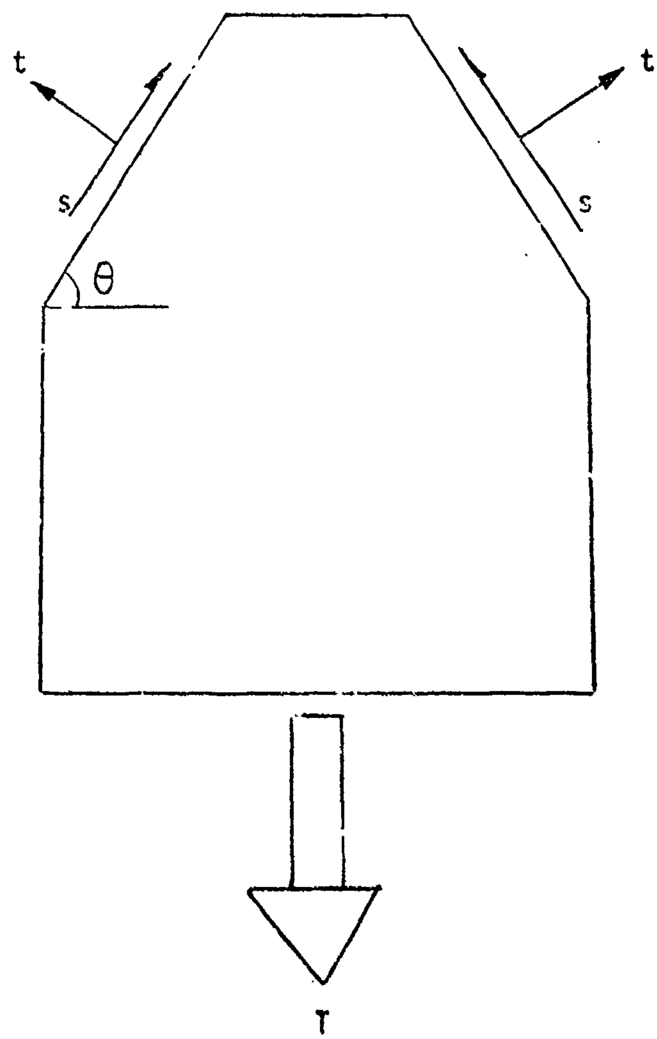


Figure 84 - Free Body Diagram of a Ruptured Fastener

is sufficiently ductile to preclude any kind of brittle failure. Under those assumptions the analysis need not concern itself with determination of the exact state of stress in the fastener or the effects of stress concentrations at various discontinuities. The ductility and the consequent yielding of the material will smear these effects across the failure surface, and it would be adequate to consider the aggregate effect for this empirical analysis. However, it is realized that the knowledge of the exact state of stress distribution is important in any fatigue or propagation analysis.

It is assumed that the fastener can fail in two possible ways:

a. Head Failure

b. Shank Failure

The head failure can result from the combined effect of shear and tension as shown in Figure 84. It can also result from cantilever type bearing when there are eccentricities in loading. The latter type of failure will not be considered in the present analysis. The failure of the shank above the threads can be treated as a special case of head failure (the case when $\theta = 0°$). The failure of the shank at the threads can be treated separately.

2. Analysis of Head Failure

In Figure 84 the failure surface is at an angle θ with the horizontal. The fastener is loaded in tension. When θ is zero degrees, the bolt fails in pure tension and when $\theta = 90°$ it fails in pure shear. For all other values of θ the failure is due to a combination of shear and tension. The equilibrium requirements in the direction of the load gives the following relation:

$$As \sin \theta + At \cos \theta = T$$

where

T = Tensile Strength of the Fastener (1)

s = Shear stress on the surface of failure

t = Tensile stress on the surface of failure

A - Area of the failure surface

For a given head and recess size, the area of the failure surface can be expressed as a function of θ ($A(\theta)$). Equation 1 can also be written as

$$As (\sin\theta + t/s \cos\theta) = T \quad (2)$$

The tensile stress t, the shear stress s, the inclination of the failure surface, and the area of the failure surface A are the four unknowns in Equation 2. Because of the nature of the axisymmetric problem, the other equilibrium equations will be satisfied for any combination of shear and tension stresses on the failure surface and consequently do not provide additional independent relations. An empirical relation between t, s and θ is assumed as follows:

$$t/s = F(\theta) = {}_{e}(C1/\tan\theta - C2\tan\theta) \quad (3)$$

The relation 3 describes the two extreme cases, pure tension and pure shear failures adequately.

a. The case when $\theta = 0°$ represents pure tension failure (no shear, s = 0).

b. The case $\theta = 90°$ represents pure shear failure (no tension, t = 0).

The intermediate cases can be represented by selecting appropriate values for the empirical constants C1 and C2. The procedure for selecting C1 and C2 will be discussed later. The third relation involving shear and tension allowables is written as follows:

$$(t/t_A)^p + (s/s_A)^q = 1 \quad (4)$$

where t_A is the maximum tension stress the material can take when it is subjected to pure tension. Similarly s_A is the maximum shear stress the material can take in pure shear. For the case when the exponent p = 2 and q = 2, Equation 4 represents the Von Mises yield criterion. For the ultimate strength prediction however, more appropriate values would be p = 2 and q = 3 (see Reference 1). It will be further assumed s_A and t_A are related by

$$s_A = \alpha\, t_A \quad (5)$$

the value of the constant $\alpha = 0.57$ can be used to predict the yield in shear by the Von Mises criterion. However, the value for α for heat treated steel can be as high as 0.85 (see Reference 2). The fourth equation is obtained by invoking the condition that the failure occurs on the weakest surface and it is expressed as

$$\frac{\partial T}{\partial \theta} = 0 \quad (6)$$

The condition represented by Equation 6 can be used to determine the value of θ. This can be done either by actually carrying out the differention indicated by Equation 6 or by plotting a graph between T and θ (see Figure 85). Then θ is the value that corresponds to the lowest value of T.

Now the procedure for the empirical analysis can be outlined as follows:

a. A set of values for C1 and C2 are assumed first.

b. The critical value of θ is determined by the relation

$$\frac{\partial T}{\partial \theta} = 0$$

c. With the value of θ determined in the last step, t/s can be determined from Equation 3.

d. For given values of s_A and t_A, the value of s can be determined from Equation 4 with t/s determined from the last step.

e. The valuse of t/s and s determined in the last two steps are substituted in Equation 2 to obtain the tensile strength corresponding to the head failure.

f. The last step is to check the validity of the constants C1 and C2 assumed in the first step. This can be accomplished by comparing the tensile strength computed in the last step with the actual test values. If they do not agree, the procedure will be repeated with a new set of values for C1 and C2.

This empirical analysis is relatively simple and convenient for parametric studies. However, the differentiation indicated by Equation 6 is not convenient because the breaks in the recess geometry makes the failure surface area a discontinuous function of θ. To avoid this difficulty, the tensile strength T can be determined for discrete values of θ and from this tabular data (or a graph) the lowest value of T and the corresponding θ can be picked. A small computer program to generate this tabular data and the necessary graphs is available.

3. Comparison of Analysis and Test Results

In this section the results obtained by the empirical analysis will be compared with the available test results. The analysis procedure presented in this report was applied to Phillips, Torq-Set, Tri-Wing

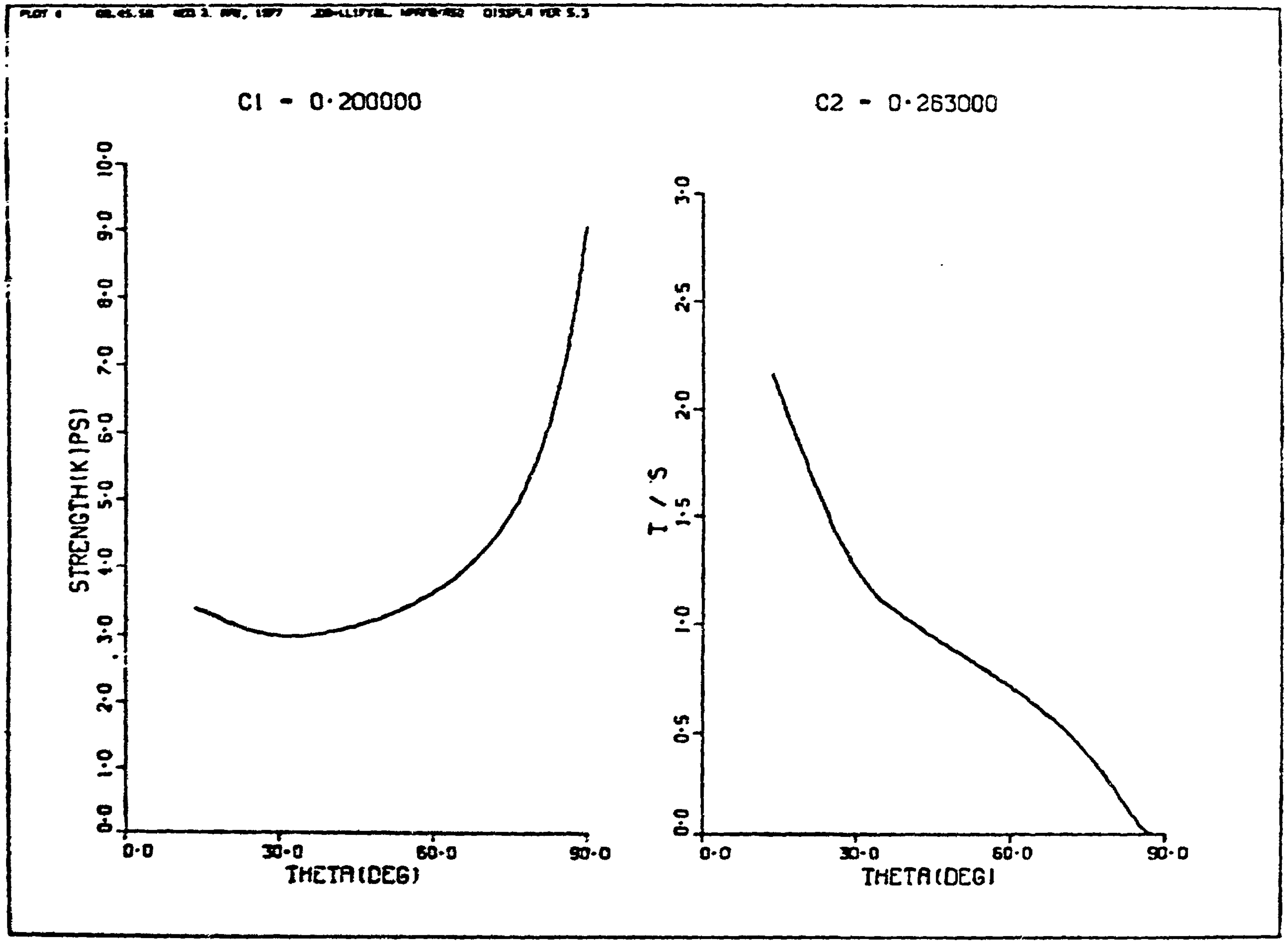


Figure 85. Typical Variation of Strength and t/s with Theta

fasteners. The same procedure with some modifications can be used for Torx and Hi-Torque fasteners.

Before proceeding with the analysis, we need an estimate of the reasonable values for the constants C1 and C2. The best way to determine C1 and C2 for each class of fasteners is to conduct at least two tests involving different angles of inclination of failure surfaces. If the test loads and the angles of inclination of the failure surfaces can be measured accurately, Equations 2 and 3 can be solved simultaneously for determining C1 and C2. The test load can be determined quite accurately. However, it would be difficult to measure the inclination of the failure surface. Another possible approach is to statistically estimate the constants for various classes of fasteners. However, this procedure requires large numbers of cases of test data. Because of these difficulties, a trial procedure involving estimation of C1 and C2 and comparing the resulting analytical strength with the test load was adopted. If the two strengths do not agree, the procedure can be repeated with a new set of constants until the results agree. To facilitate this comparison, a computer program that determines analytical strengths of fasteners for desired ranges of constants C1 and C2 is available from the Air Force Flight Dynamics Laboratory.

The initial estimate of the constants C1 and C2 is obtained by considering two extreme cases. For small angle of inclination of failure surface, the failure is assumed to be predominantly due to tension. Similarly for large angles (close to 90°) the failure would be primarily due to shear. Considering 5° and 85° as representing these two extreme cases, Equation 2 can be written as

$$As\ (\sin 5° = t/s \cos 5°) = T$$

$$As\ (\sin 85° + t/s \cos 85°) = T$$

For these two extreme cases, the following additional relations will be assumed.

$$As = 0.85\ At_A$$

$$As = At_A$$

Cancelling T and At_A the values of t/s for the two inclinations can be written as

$$t/s|_{5°} = 1.1$$

$$t/s|_{85°} = 0.04$$

Substition of these two values in Equation 3 gives

$$1.1 = e^{11.43C1 - 0.087C2}$$

$$0.04 = e^{0.087C1 - 11.43C2}$$

Taking natural logarithms on both sides and solving for C1 and C2 gives the following values:

$$C1 \approx .01 \qquad C2 \approx .28$$

The approximations in the foregoing discussion are intended only for initial estimate of C1 and C2 and are not acceptable for actual analysis. The present estimate for the range of C1 is between 0 and 0.6. The range for C2 is between 0.1 and 1.0.

A few test results are available for Phillips, Torq-Set, and Tri-Wing fasteners. The fasteners are classified as tension and shear heads. The distinction is that in case of tension heads the sizes of both the shank and the head are described by the same number. In case of shear heads however, the head is one size smaller than the shank. Table 14 contains the description and relevant dimensions of the fasteners for which the test data is available (see Reference 3). The first five fasteners were tested by Standard Pressed Steel (SPS) Corporation for the Air Force on the fasteners supplied for the tests described in Section II. Table 15 contains the results. The first two columns of this table gives strength of the fasteners as determined by test and analysis. The next two columns are the values of the constants C1 and C2 used in the analysis. The values of t/s and the corresponding values of θ, the angle of inclination of failure surface are given in the next two columns. The last column lists the percentage difference between the strengths determined by test and analysis. In most cases, this differences is less than ten percent.

The results in these two tables indicated that it is possible to predict the static strength of the fasteners with reasonable accuracy by the empirical analysis presented in this report. However, we have not established a rational approach for estimating the values of the constants C1 and C2 for a given fastener. A number of factors can effect the values of C1 and C2. The shape of the recess, the relative dimensions of the head and the recess, and metalurgical structure around the recess are some of the factors that can effect the constants C1 and C2. Additional test data is necessary to determine how and to what extent these factors can influence C1 and C2.

TABLE 14

FASTENER DIMENSIONS

FASTENER DESCRIPTION	SDIA *	RDIA *	RBDIA *	HDEP *	RDEP *	RBDEP *
Phillips (Shear)	0.189	0.162	0.0984	0.049	0.0928	0.0749
Tri-Wing (Shear)	0.189	0.21	0.935	0.049	0.1308	0.0610
Tri-Wing (Tens)	0.189	0.244	0.140	0.083	0.0800	0.0545
Torq-Set (Shear)	0.189	0.215	0.094	0.049	0.0780	0.0609
Torq-Set (Tens)	0.189	0.248	0.109	0.083	0.08996	0.07016

* See Figure 83 for Dimension Identification

TABLE 15

FASTENER TEST RESULTS

	FASTENER DESCRIPTION	TENSILE STRENGTH (lbs) TEST	TENSILE STRENGTH (lbs) ANALYSIS	C1	C2	t/s	θ IN DEG	% DIFF IN STRENGTH
TENSION HEADS	TORQ-SET (121693-B)	3732.5	3230.0	0.56	0.2	1.402	45.83	-15.6
	TRI-WING (121693-D)	3687.5	3234.0	0.56	0.2	1.282	49.32	-14.02
SHEAR HEADS	PHILLIPS (121693-H)	2411.3	2522.0	0.1	0.2	1.261	18.5	+4.59
	TRI-WING (121693-K)	2445.0	2269.0	0.1	0.2	0.996	35.7	-7.76
	TORQ-SET (121693-I)	2099.0	2202.0	0.1	0.2	0.959	39.32	+4.91

4. Variation of Strength of the Fastener with Depth of the Recess

An analytical study was made to determine how the strength of the fastener varies with the depth of the recess. The study includes the fasteners discussed in the previous section. The constants C1 and C2 given in Table 15 are used for the respective fasteners. The assumption that these constants are valid for the entire depth variation is questionable however. It is assumed that the recess diameters are constant, and they are given in Table 14. The depth of the recess is varied as shown in Figure 86 for all the fasteners. In the first case, the depth of the recess is varied keeping the recess diameter at the top and side slopes constant. The slope of the recess is determined by the dimensions given in Table 14. In the second case, the recess diameter at the top (RDIA) and at the bottom (RBDIA) were kept constant while varying the depth. The results are presented for each fastener in the form of graphs. The strength of the fastener is normalized by gross tensile strength of the fastener in all cases. The normalizing strength is given by:

$$T_0 = \frac{\pi(SDIA)^2}{4} t_A$$

It should also be pointed out that only head failure is considered in this analysis.

5. Discussion

The analysis presented here is adequate to determine the static strength of the fastener with respect to head failure. It can be used quite effectively for parametric studies involving changes in dimensions of the recess. The purpose of these parametric studies is to determine optimum dimensions of the recess with the desired torque characteristics. It is also necessary that the recess does not significantly reduce the strength of the fastener. When a fastener fails, the mode of failure determines the effort required for replacement. It appears that a head failure is preferable over thread failure. This requirement can be incorporated in the design of the fastener by adjusting the recess dimensions.

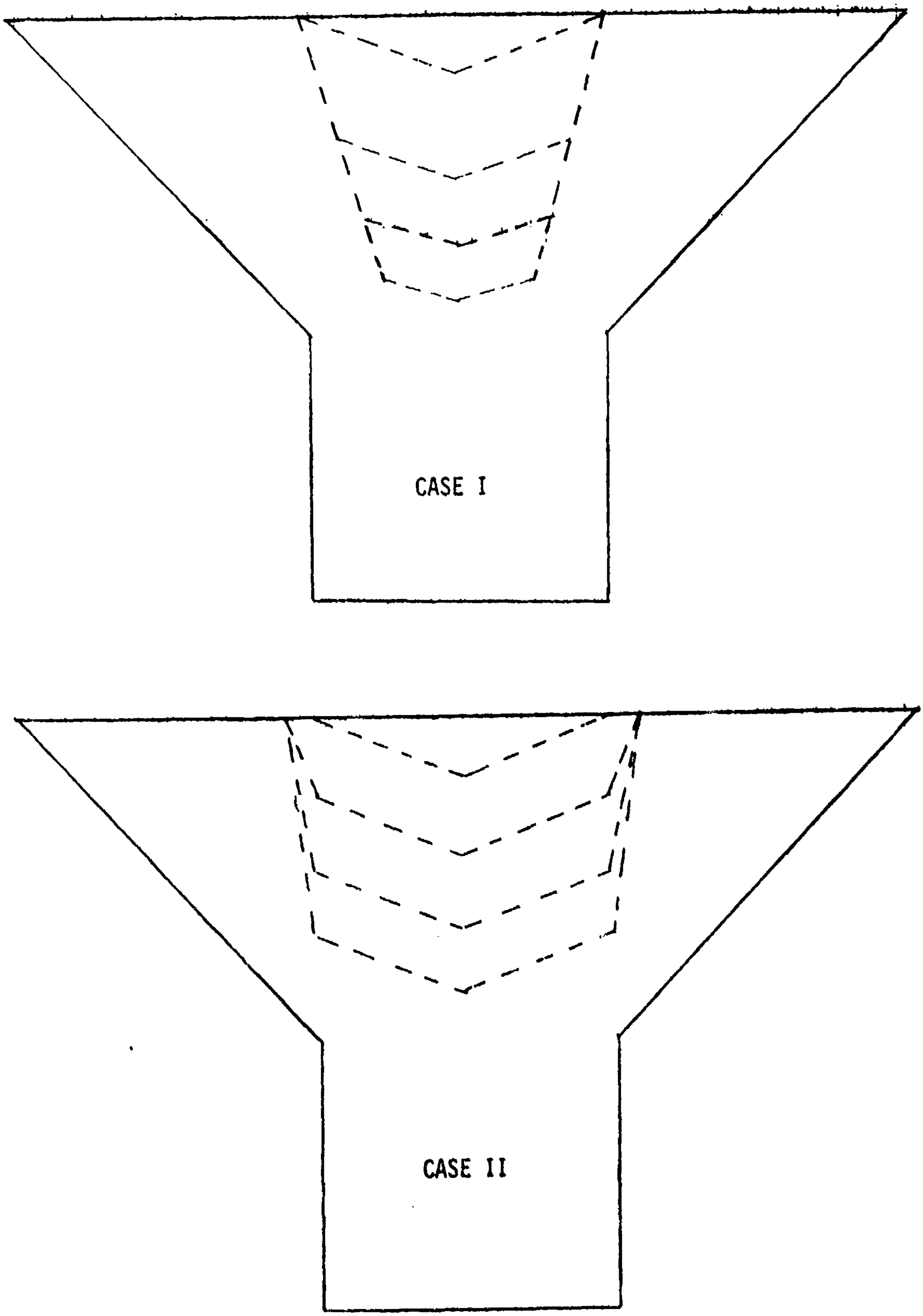


Figure 86 - Recess Depth Variation

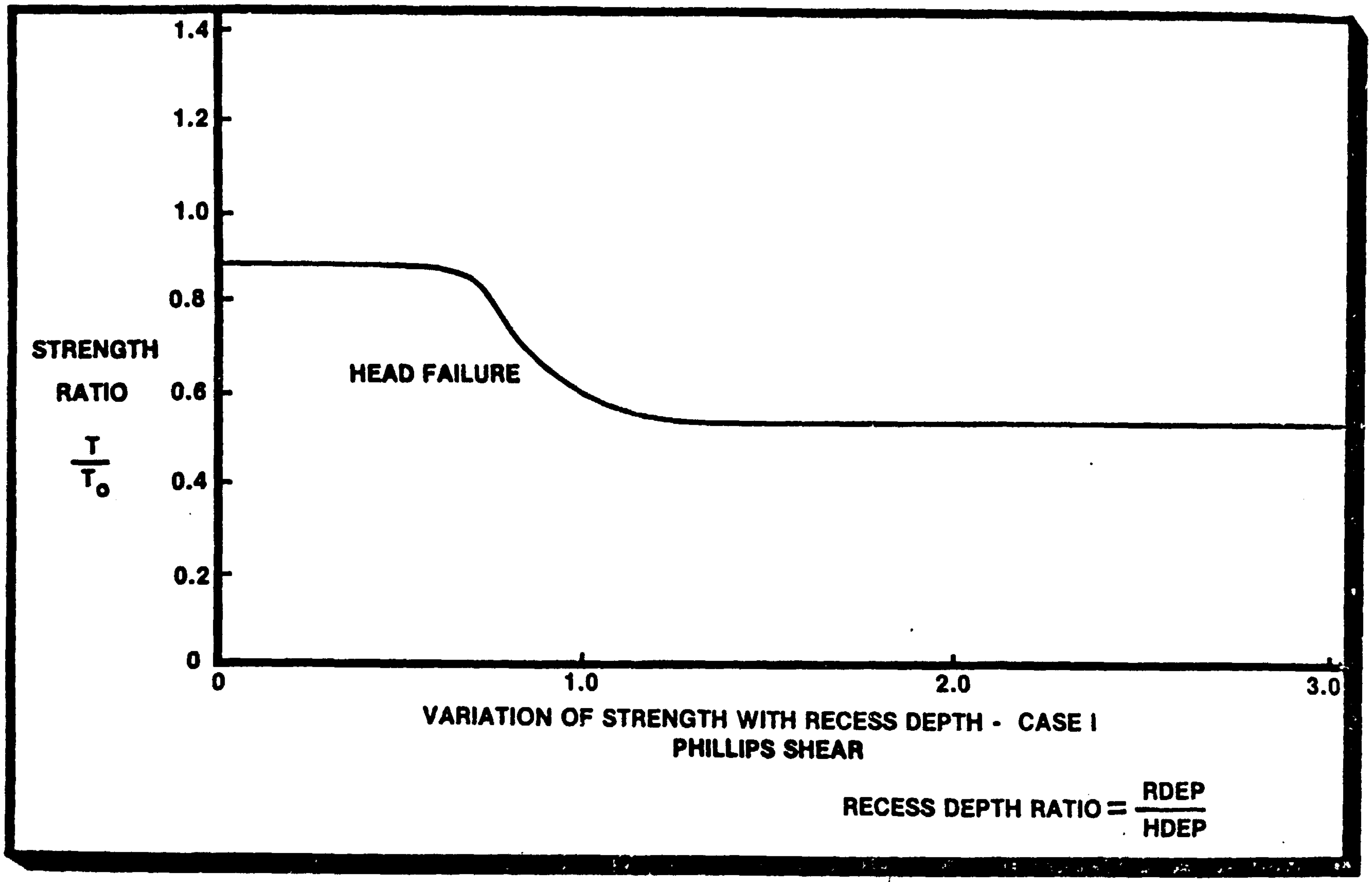


Figure 87 - Analytical Results for Case I on the Variation of Tensile Strength with Recess Depth

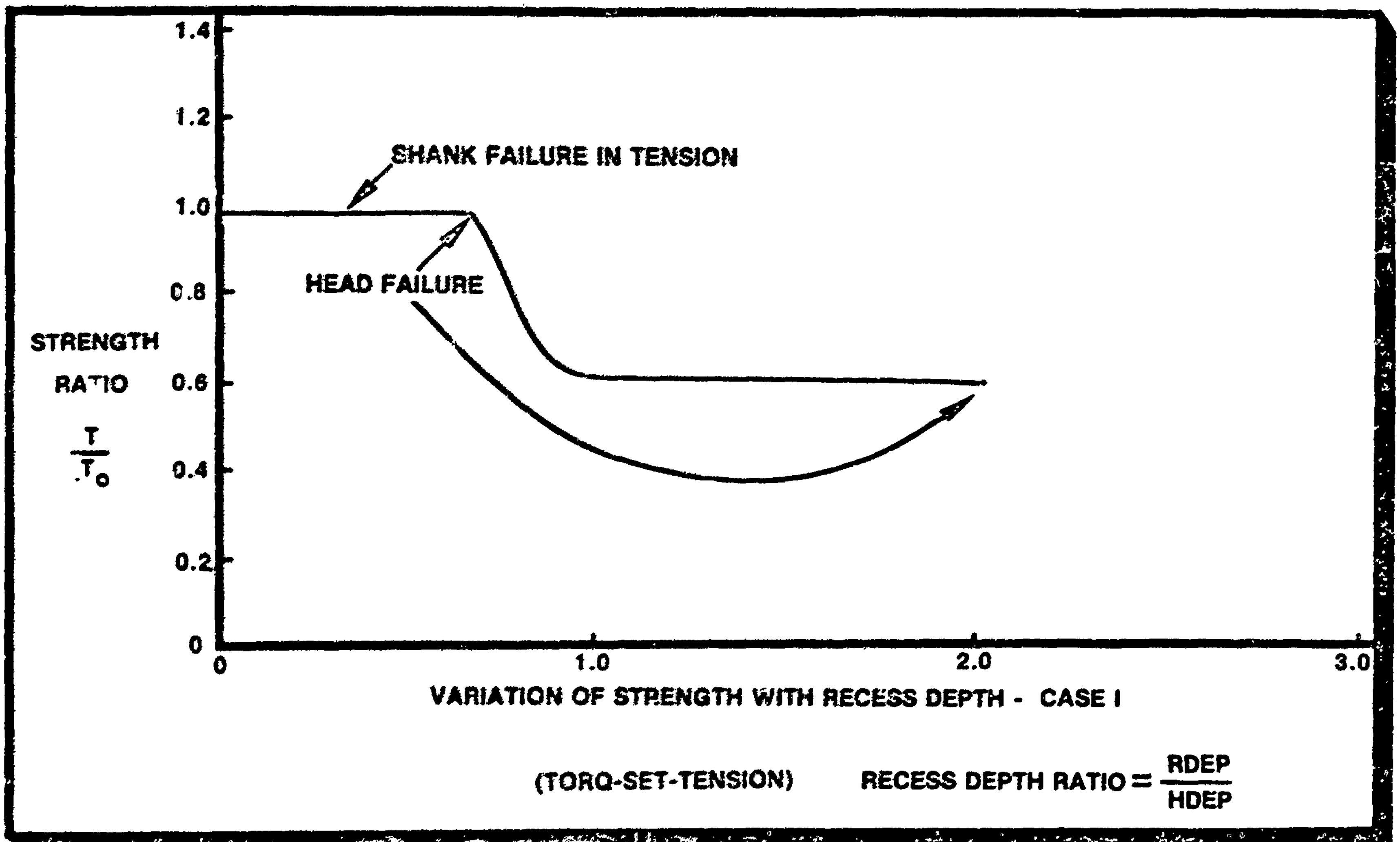


Figure 88 - Analytical Results for Case I on the Variation of Tensile Strength with Recess Depth

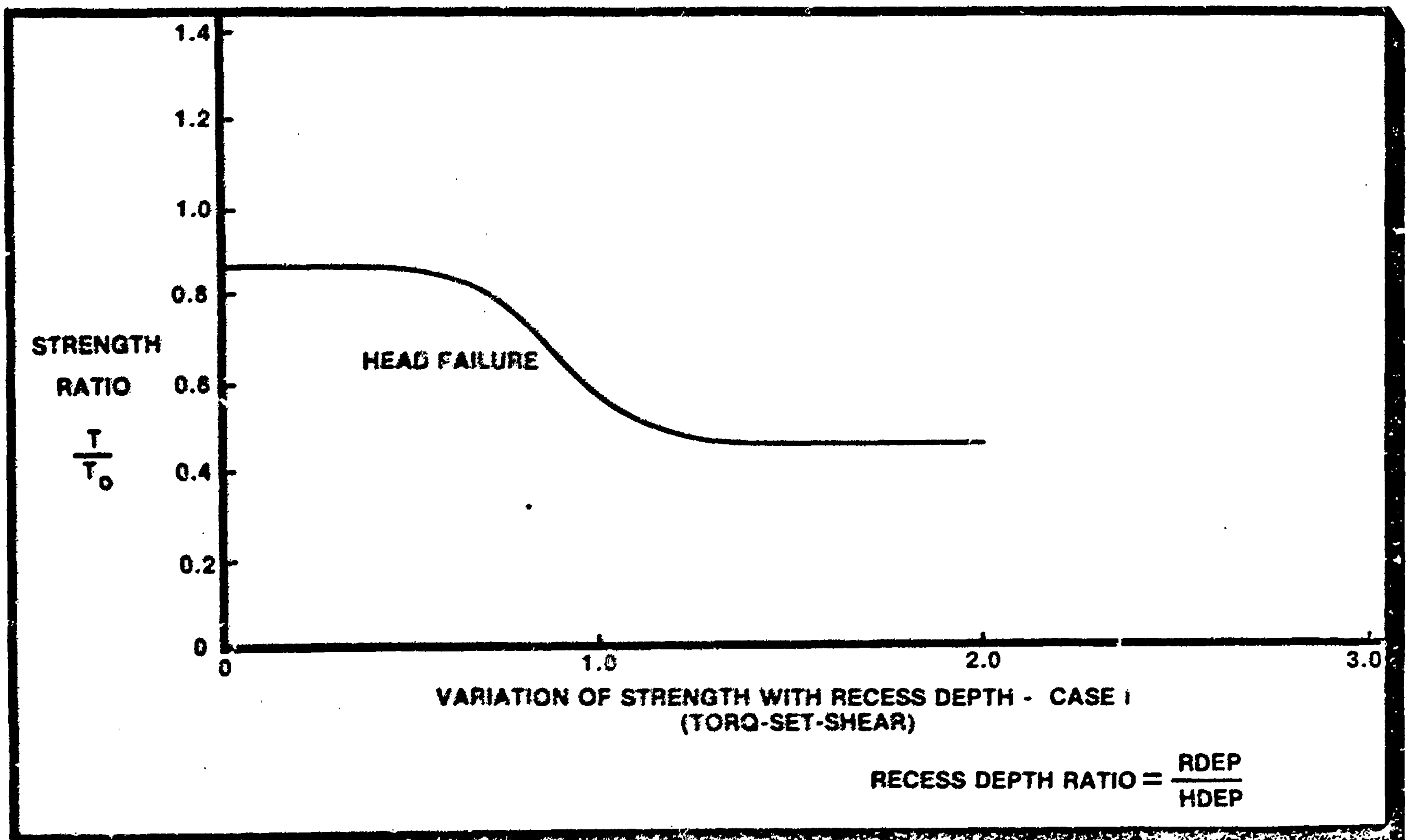


Figure 89 - Analytical Results for Case I on the Variation of Tensile Strength with Recess Depth

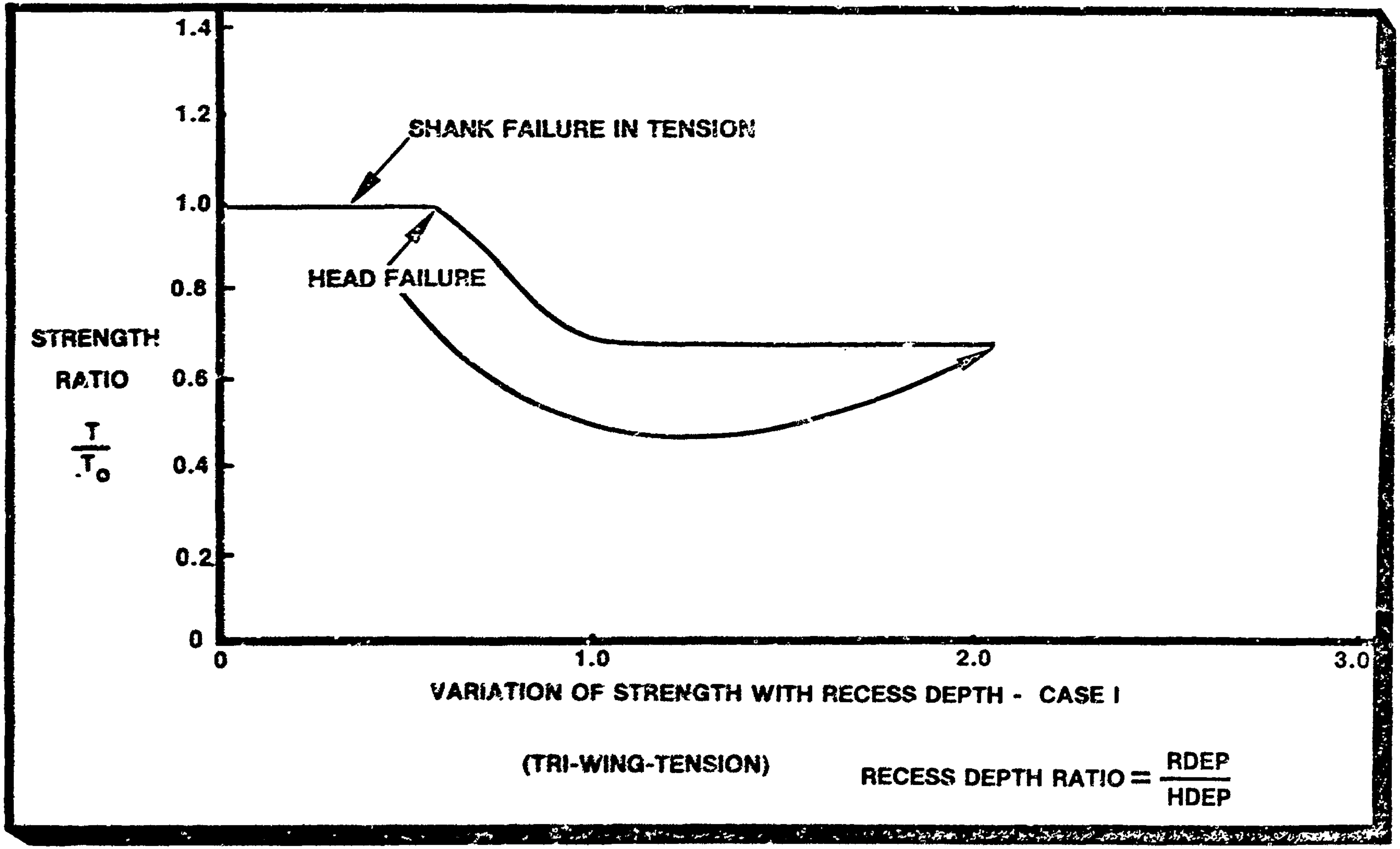


Figure 90 - Analytical Results for Case I on the Variation of Tensile Strength with Recess Depth

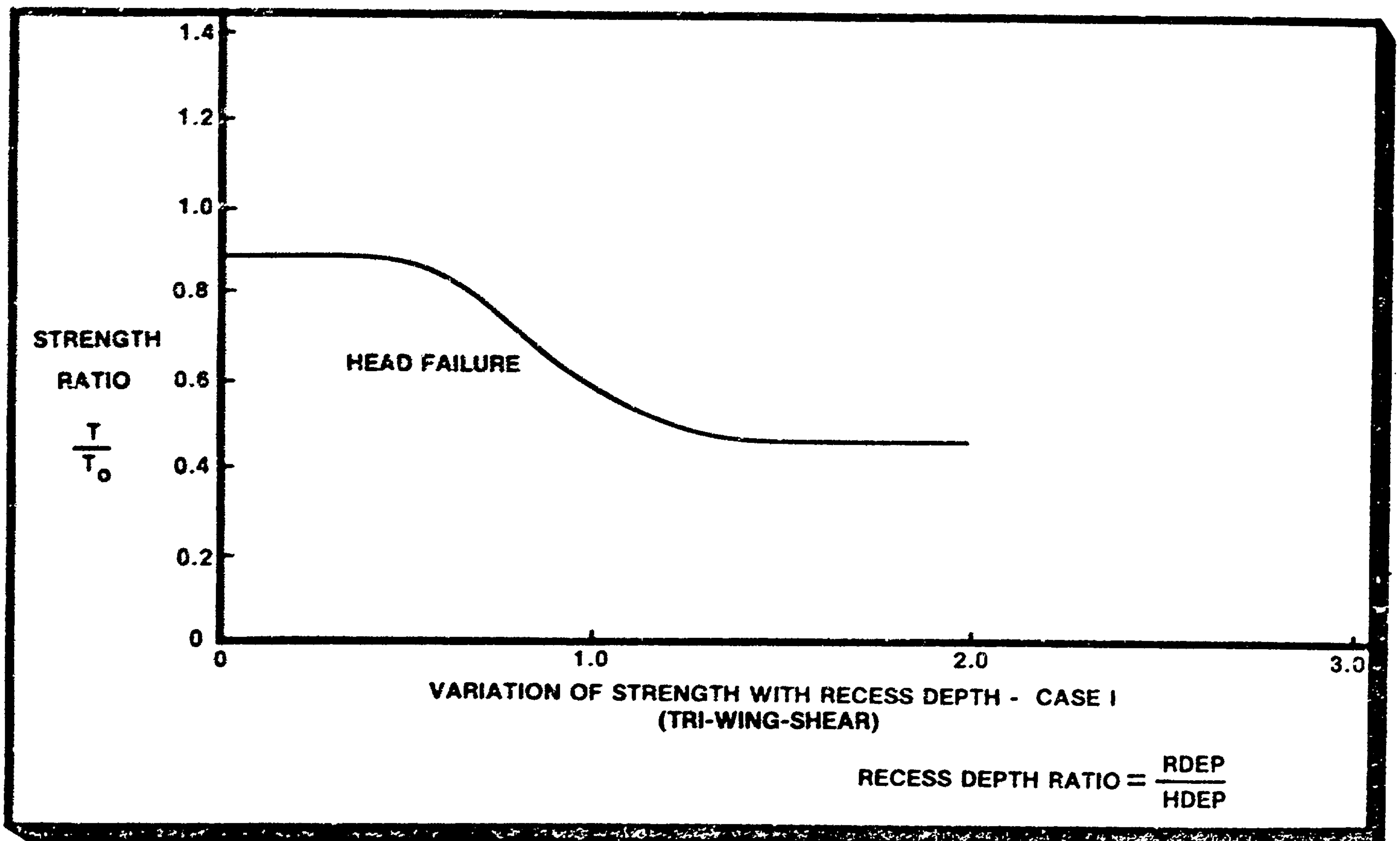


Figure 91 - Analytical Results for Case I on the Variation of Tensile Strength with Recess Depth

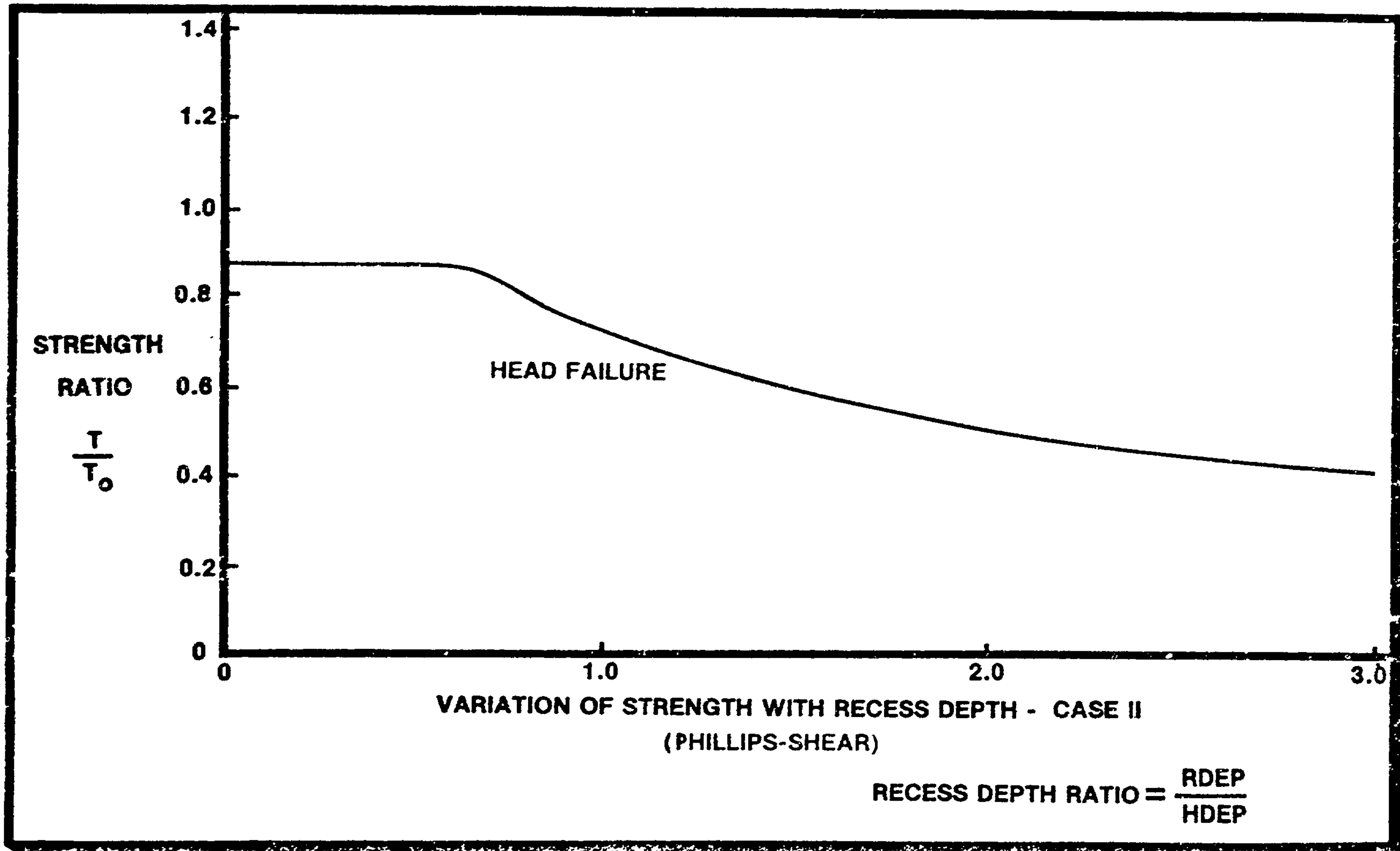


Figure 92 - Analytical Results for Case II on the Variation of Tensile Strength with Recess Depth

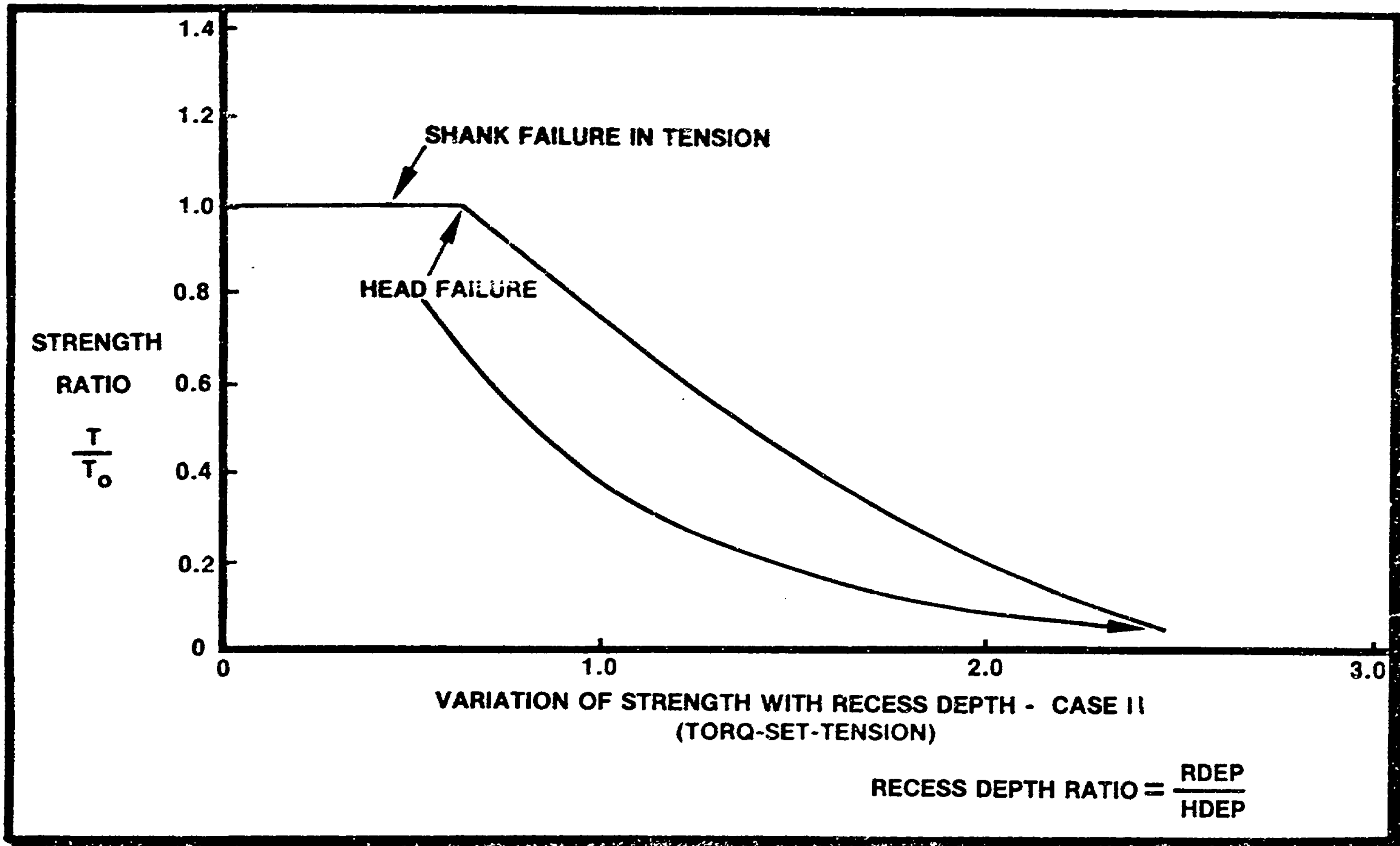


Figure 93 - Analytical Results for Case II on the Variation of Tensile Strength with Recess Depth

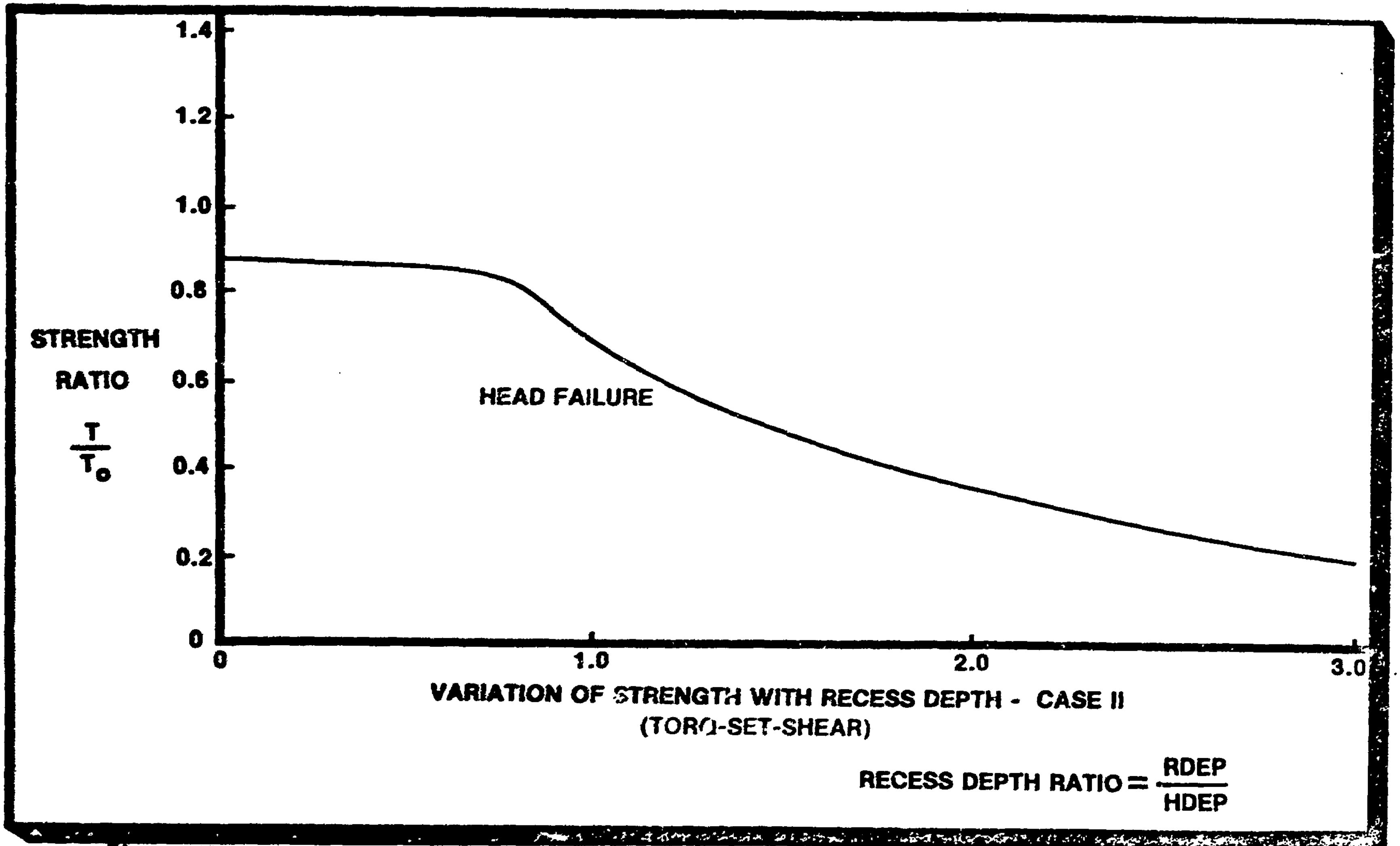


Figure 94 - Analytical Results For Case II on the Variation of Tensile Strength with Recess Depth

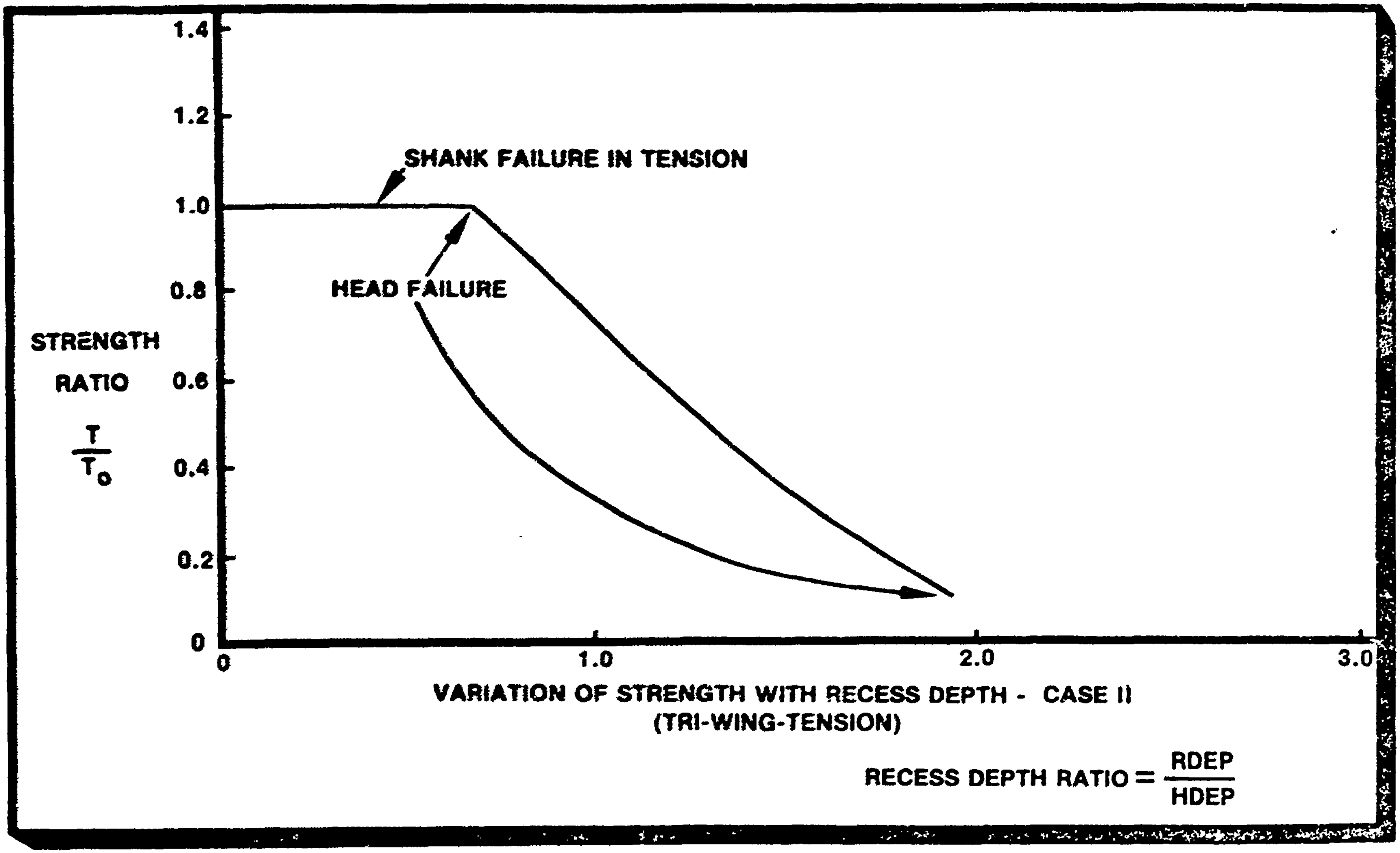


Figure 95 - Analytical Results for Case II on the Variation of Tensile Strength with Recess Depth

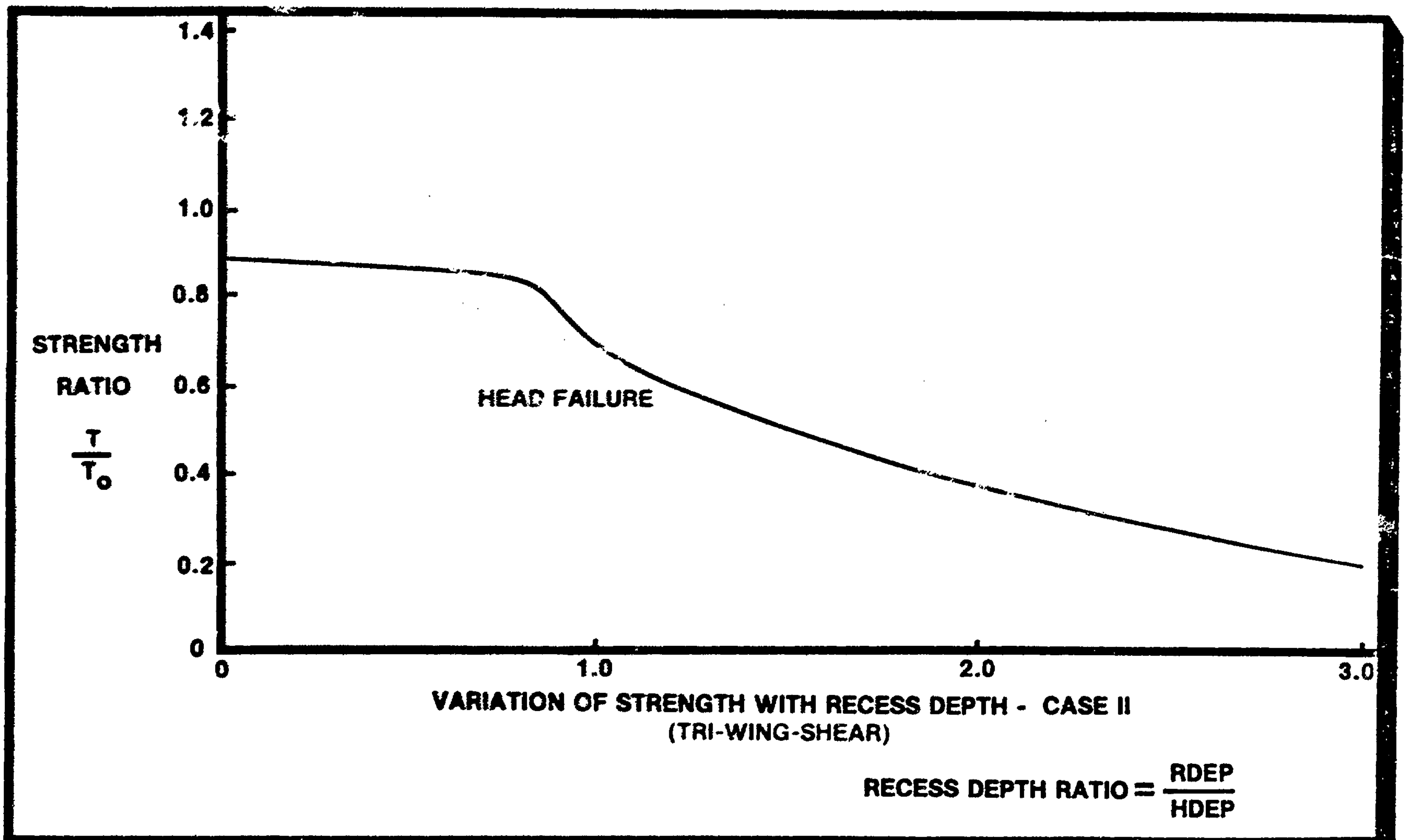


Figure 96 - Analytical Results for Case II on the Variation of Tensile Strength with Recess Depth

SECTION V

FIELD DATA MEASUREMENTS

In order to adequately design any useful product, the engineer must know the conditions under which it will be used. Knowing the conditions will allow the designer to vary specific design features to achieve the desired results. For recess fasteners, the desired result is to apply sufficient torque to the fastener to cause it to be installed in place and to be removed when desired.

During installation and removal, torque is applied as well as end load and offset angle of the driver. These parameters are imposed by the mechanic. The characteristics of the mechanic (training, size, etc.) as well as the geometry of the work situation will affect the levels of torque, end load and angle. In order to find out just what these values are and how some of these parameters affect the imposed conditions, field measurements were taken. A team visited units of three commands at Wright-Patterson AFB, Davis-Montham AFB, Langley AFB, Nellis AFB, and Edwards AFB. Data was taken on the following aircraft: A-7, A-10, F-15, F-106, F-4, F-16, F-5, and NKC-135. Over 2,000 data trials were accomplished.

1. Test Equipment

The test equipment was an instrumented speed wrench and data recorder.

A picture of the instrumented speed wrench is shown in Figure 97. The box below the handle contains the force (end load) and torque transducers. These transducers are mounted on a single beam. In order to insure a separation of measurement, this beam had to be relatively large. This caused the weight of the speed wrench to be relatively heavy at 4 1/4 lbs compared to 3/4 lb for uninstrumented speed wrench. The cylindrical body at the tip of the tool is the angle transducer. The plate that contacts the surface is spring loaded. The legs holding the plate are arms of a potentiometer. Through the relative resistance measurements, the angle of the plate is determined. Note that the angle transducer measures angle only, not direction of the angle.

The speed handle was connected by a cable to the strip chart recorder. The recorder is shown in Figure 98. The recorder charted all three parameters of torque, end load, and angle. Provisions are provided to control the speed of the chart and to calibrate each data channel.

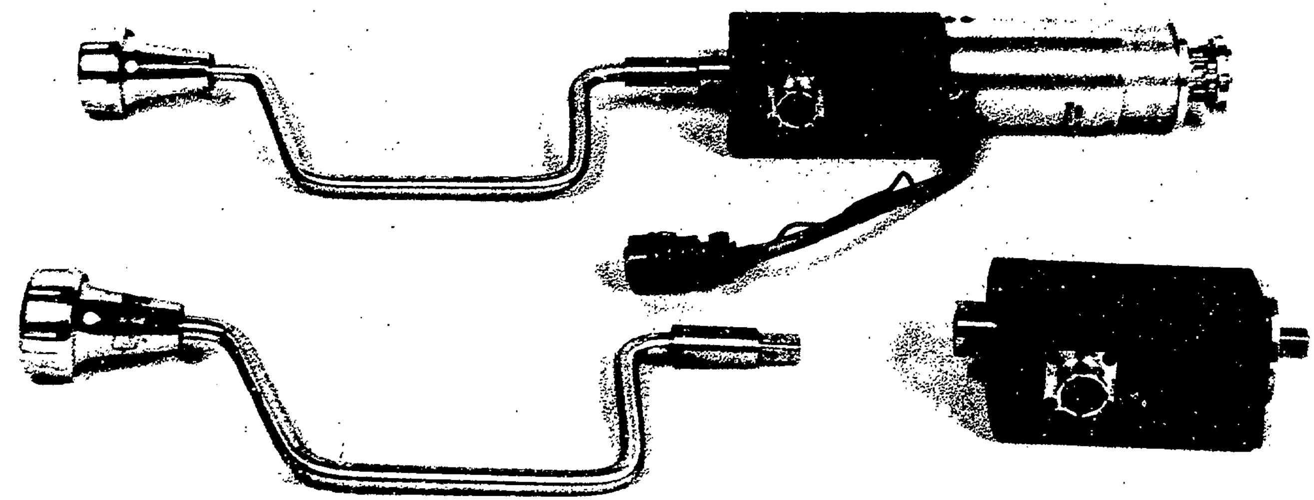


Figure 97 - Instrumented Speed Wrench

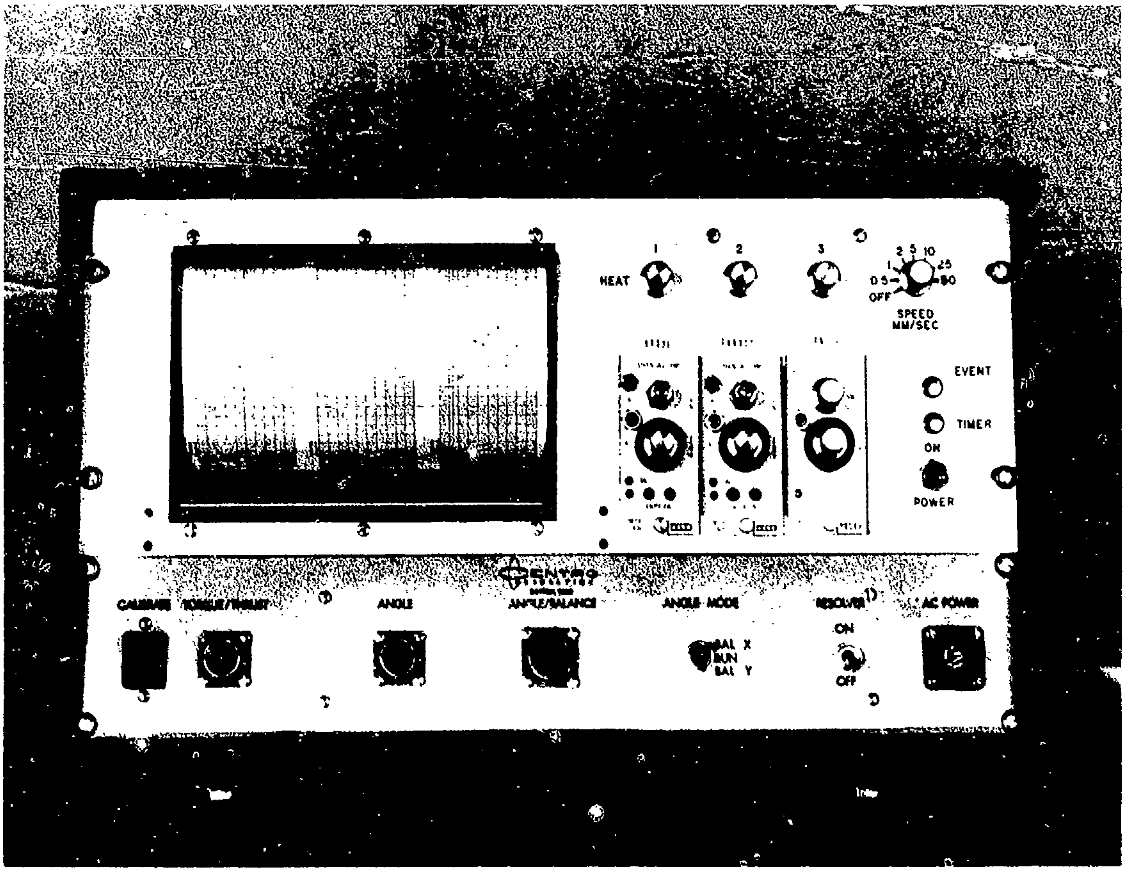


Figure 98 - Strip Chart Recorder

2. Field Data Collection Procedures

The purpose of the field data collection was to establish mean and extreme values for torque, end load, and angularity applied by organization-level aircraft maintenance personnel for use in choosing the proper values for the laboratory testing. In addition, the opinions and general impressions of maintenance personnel were recorded.

The maintenance personnel were chosen for weight, experience, hours on duty, and availability. Panels on an aircraft were chosen for orientation, screw type, and degree of comfort afforded a person working on the panel. The individual screws were chosen for shank size, head configuration, recess type, and initial condition of the recess.

After arrival on base and briefings to the Chief of Maintenance and others, the team usually went to phase dock since power and security would not be problems, and maintenance personnel from field and organizational maintenance squadrons were available. After discussion with the dock superintendent on the availability of particular aircraft, the team members chose the first aircraft, obtained electrical power, and set up the equipment. As one team member made adjustments and calibrated the equipment, the other went to the aircraft to mark the screws to be worked in the various panels. After discussion with the supervisor, a maintenance person was chosen. Preliminary information was recorded on the data sheets, and the recorder roll was marked.

The "maintainer" was briefed (with emphasis placed that this was a study of the fastener, and individuals were not "graded") and allowed to practice with the equipment. The recorder calibration was checked, and people moved to the first panel. The maintainer was to choose the proper bit, engage the fastener, loosen it several turns, pause, and tighten it until it was properly tightened (whatever that meant to the individual). This was repeated for other fasteners on the panel and for other panels, insuring that the three orientations were included. The panels used on each aircraft for these tests are shown in Figures 99 through 106. The maintainer was shown the chart after all fasteners for that individual had been completed.

The equipment was recalibrated and the procedure was repeated with different fasteners in the same panel and a different maintainer person. When that set on a given panel was finished, panels on the other side of the aircraft were chosen for two more maintainers.

At the end of each day, the following information was extracted from the charts for each loosening or tightening and entered on the data sheets:

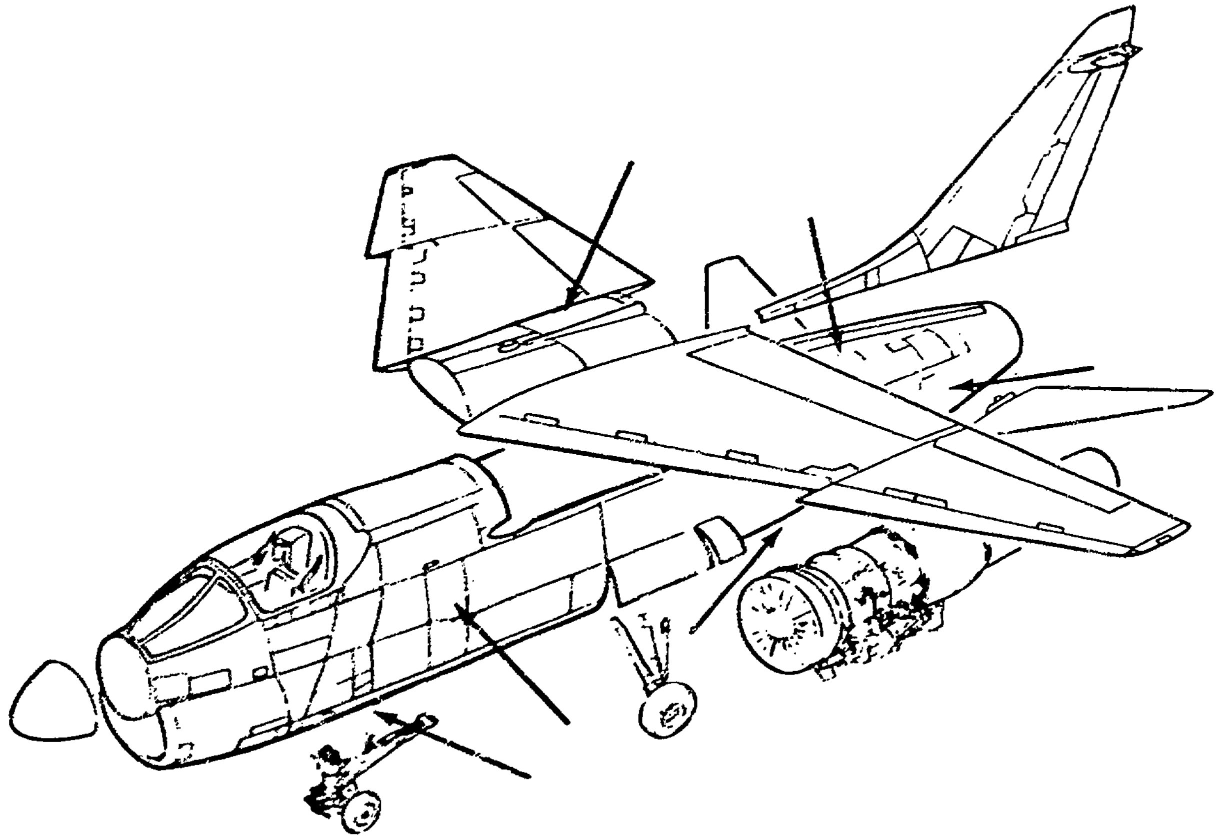


Figure 99. A-7D Panel Locations

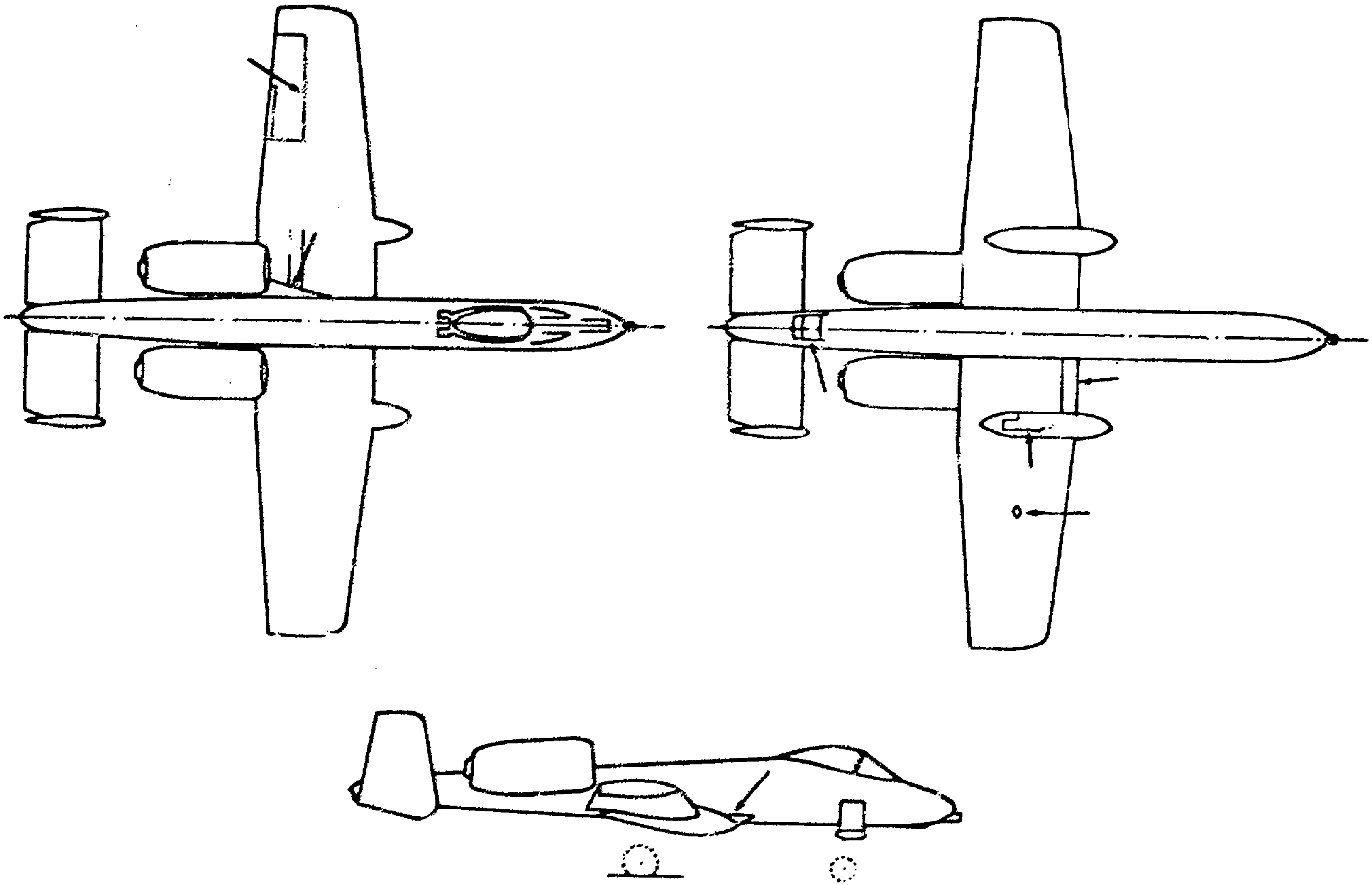


Figure 109. A-10 Panel Locations

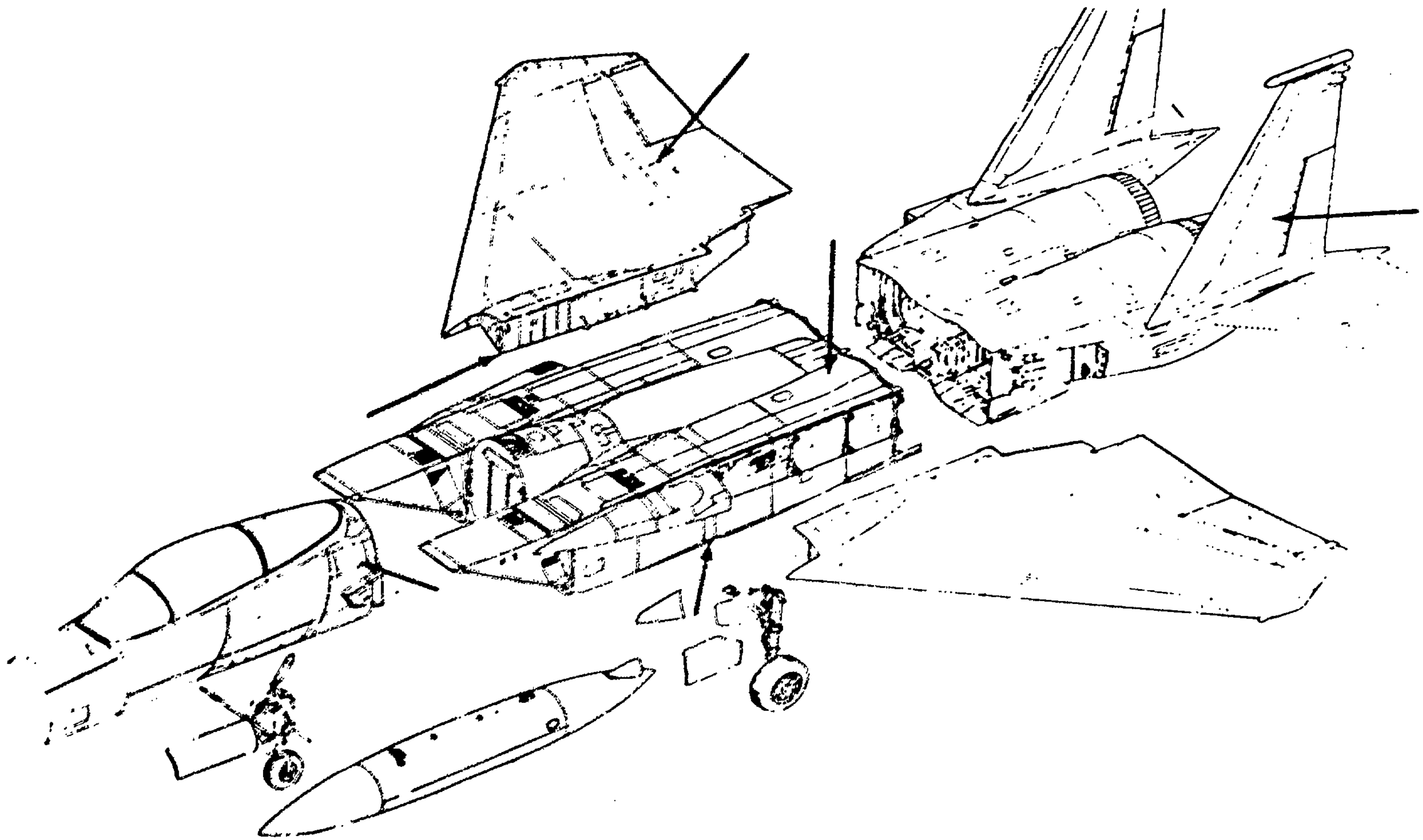


Figure 101. F-15 Panel Locations

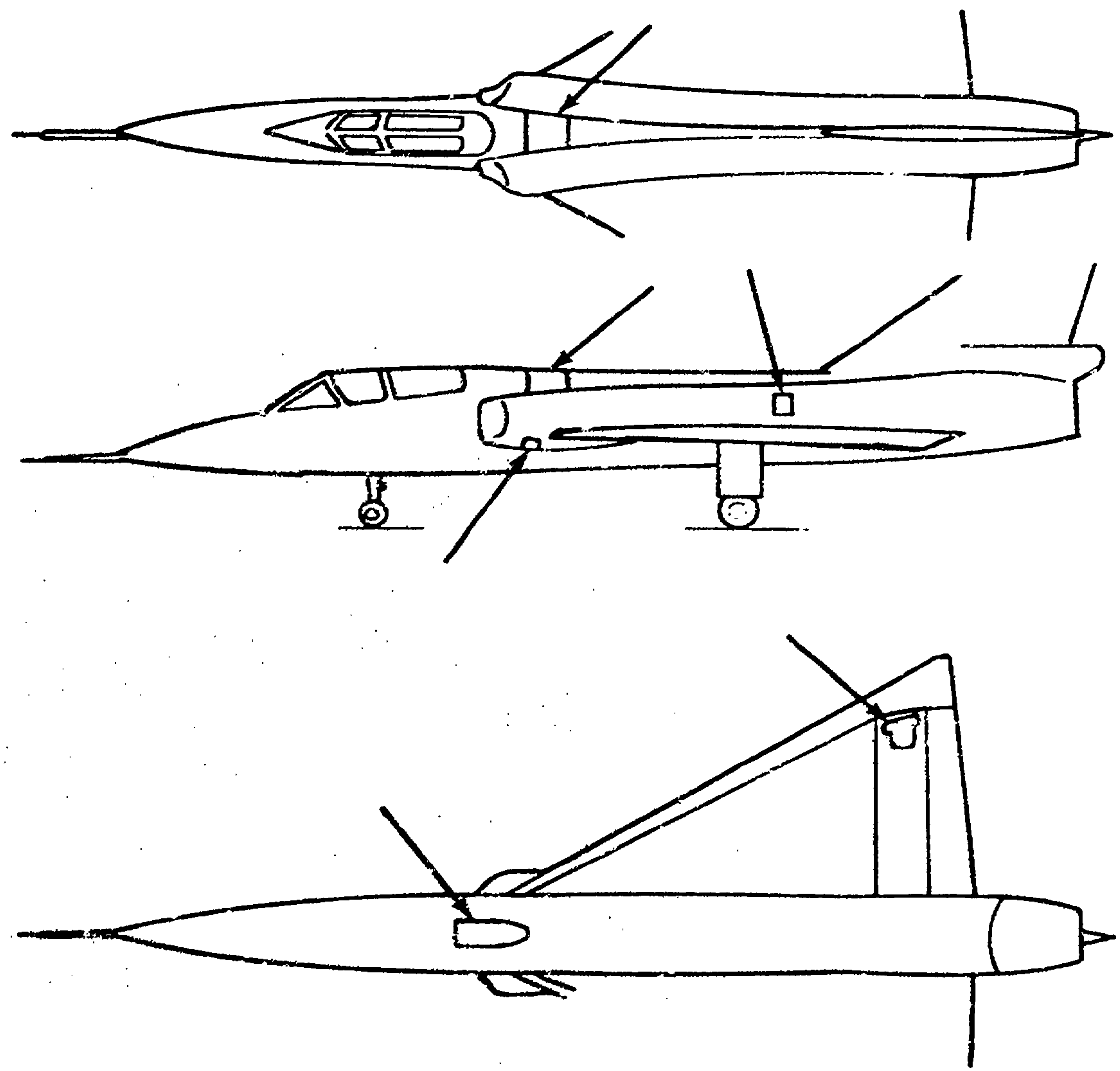


Figure 102. F-106 Panel Locations

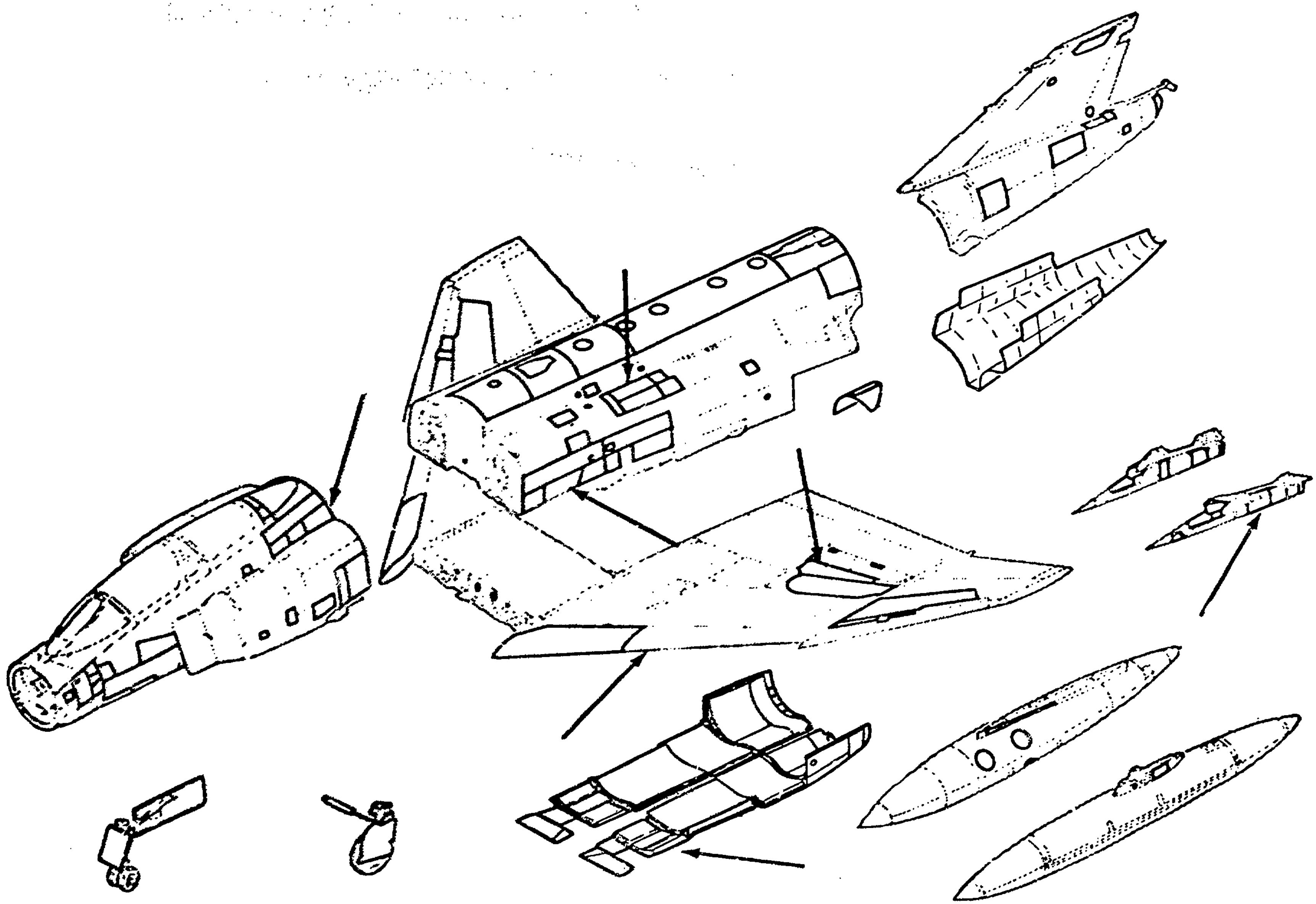


Figure 103. F-4 Panel Locations

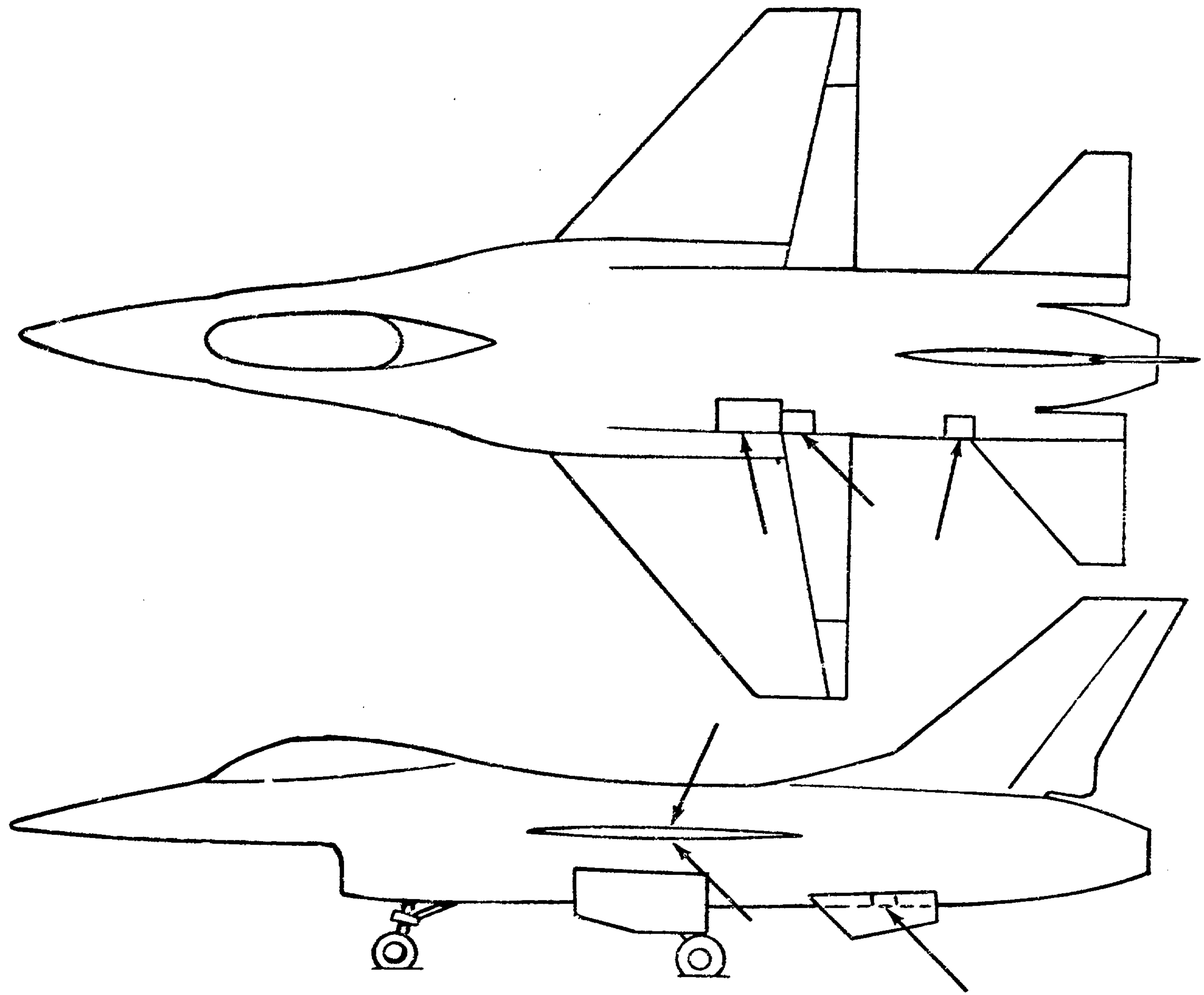


Figure 104. F-16 Panel Locations

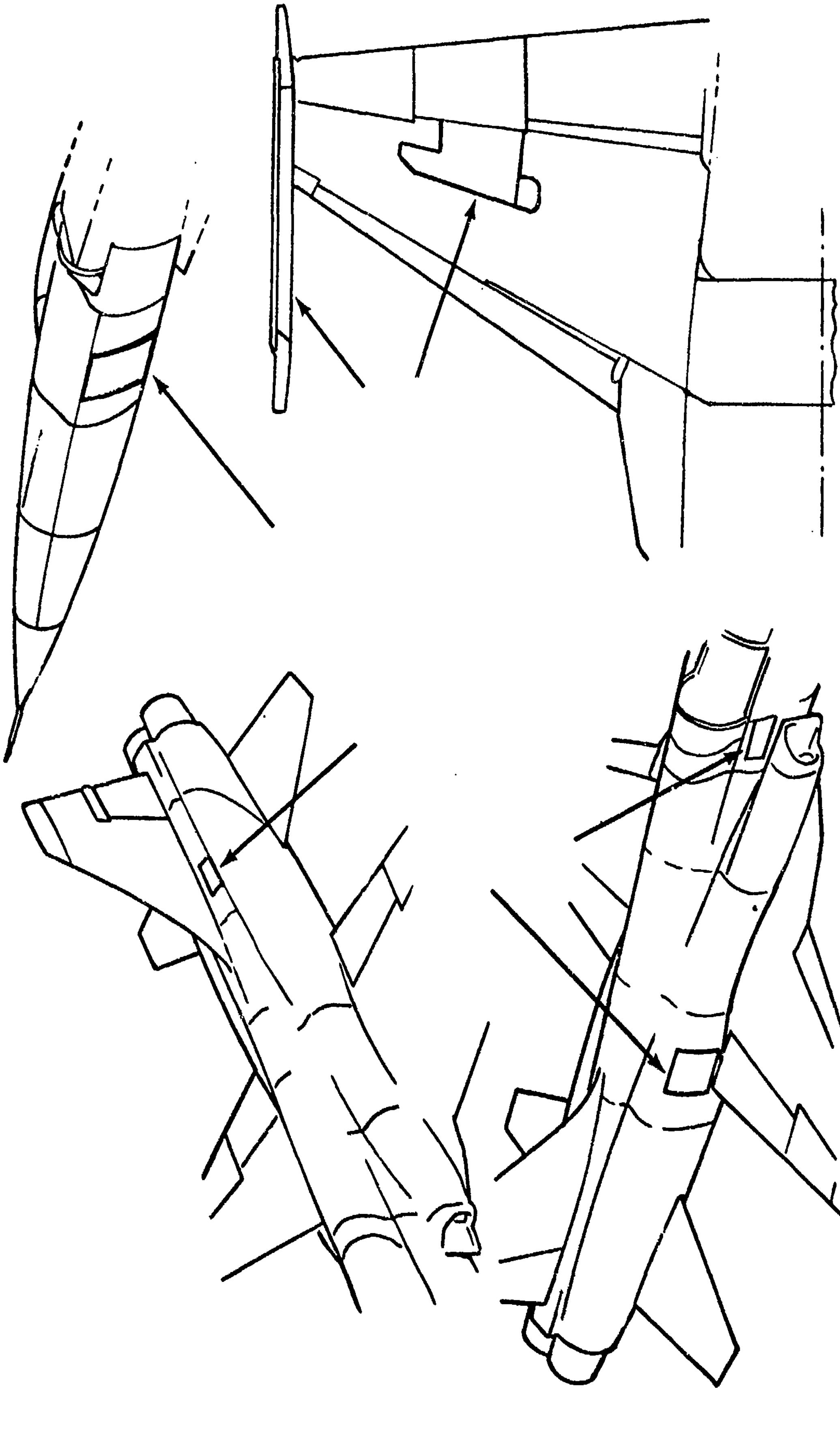


Figure 105. F-5 Panel Locations

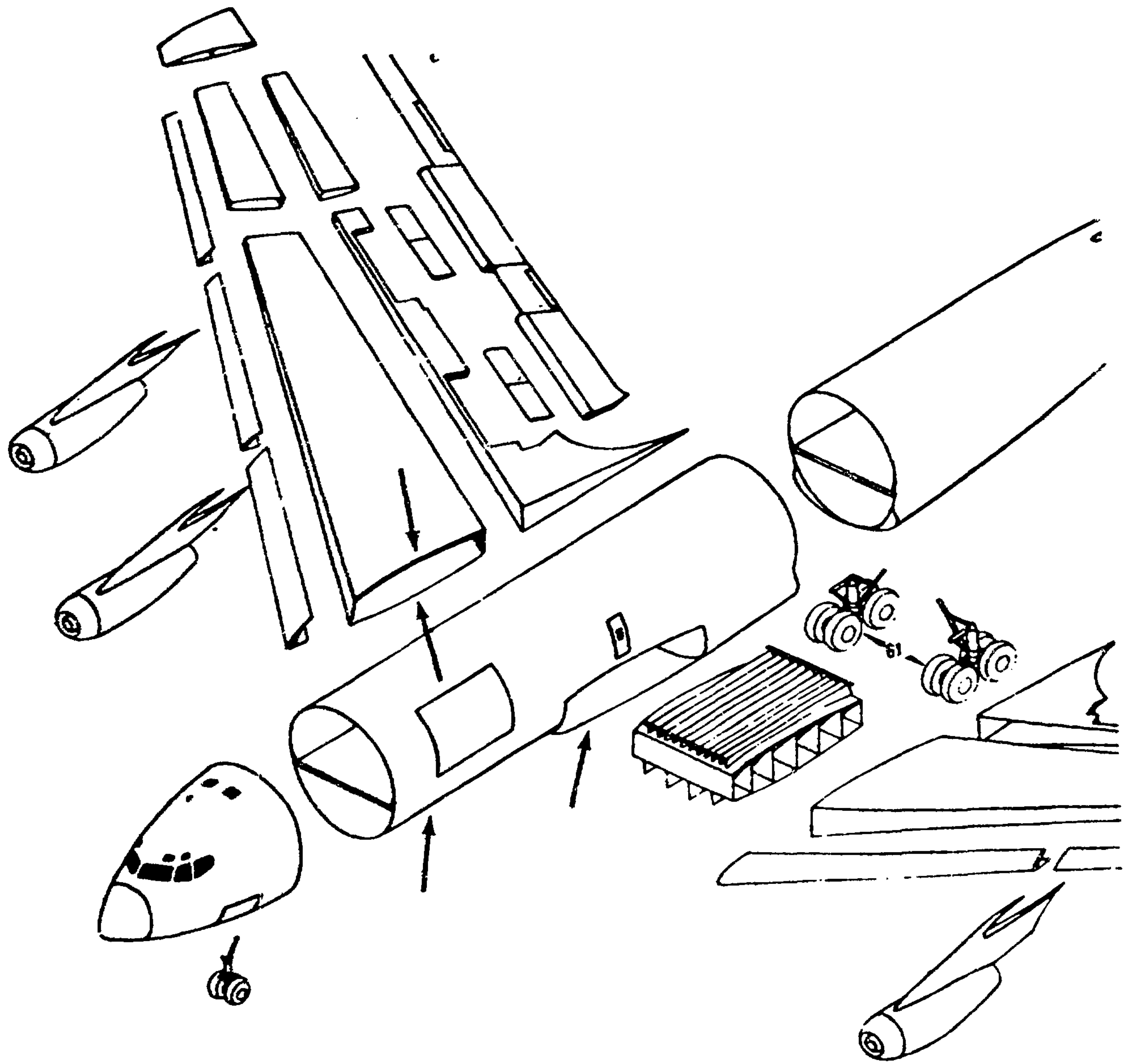


Figure 106. KC-135 Panel Locations

a. maximum torque

b. end load at maximum torque

c. maximum end load

d. angle at maximum torque

e. maximum angle

At the end of the trip, the Chief of Maintenance was briefed on general observations.

After return, the data was coded for input into the computer. A statistical program was used to assist in analyzing the data.

3. <u>Field Results</u>

There are some overall observations of the data that should be made prior to reviewing the statistical data.

First, the degree to which the results are an actual reflection of the real world is not known. When one is being watched and measured, the results are not necessarily indicative of reality. This has been well documented by the classic "Hawthorne Productivity Tests" conducted by Bell Laboratories in the early 1930's. One data item, however, is not affected by this phenomenon. This is the removal torque value. As all of the panels had been installed prior to our base visits possibly by mechanics who were not test subjects, the removal torque is a real world value. The other parameters were subject to the test conditions with the possibility of being affected by them.

Second, the overall removal torque averages may have been affected by local prior conditions. At one base, the "Yankee" screwdriver -(it converts up and down ratcheted motion into torque)- was used extensively. This tool tends to limit the maximum installation torque. Another base had just received some A-10 aircraft from the factory. Unexpectedly, the removal torque values on these aircraft were surprisingly low, some as low as 5 inch pounds. As this program progressed from September 1976, increased awareness of the problems caused by excessively high installation torques may have caused the A-10 System Program Office to raise the awareness of the factory installer to "go easy" on torque levels.

Third, the data distribution is not symmetrical about the average. The data shows a relatively low average with a large amount of data scatter to the higher values. Because of this characteristic of the data, standard deviation values are not valid. Accordingly, the average and maximum values are given.

The fourth observation has to do with the angle measurement. The data shows that the angle is constantly changing. The typical strip chart recording shows the angle to be varying in sine wave fashion. This can be accounted for by the operation of the speed wrench. As the mechanic turns the handle, he imparts a change in the relative position of the entire tool. The result is a "coning" action in the recess. The average values given in the report are derived from angles present at the time of maximum torque application.

Finally, a review of the strip charts indicates that the maximum torque and maximum end load values tend to coincide. As the chart is viewed, these values peak together. The mechanic will bring the maximum efforts to bear at the same time thereby minimizing his overall effort.

Field Torque Values

A summary of the field torque values is given in Table 16. The average removal torque values are surprisingly low. There is a remarkable consistency between styles of values with one exception; the 1/4 shear Torq-Set fastener removal torque is almost 1/2 the value of the Hi-Torque fastener. The reason for this is not known. The A-10 aircraft referred to earlier with low removal torque values have Hi-Torque recesses and would have affected only that value.

The average installation torque values are not too high. They are at the high end of NAS 1737 recommended values for 3/16 size fasteners and lower than the recommended values for the 1/4 inch size.

Field End Load Values

The field measured end load values are summarized in Table 17. The Phillips recess required consistently higher end loads than the Torq-Set recess which is similar in style. This is probably related to the different slope in the sides of the recess which allow the tool to back out more easily in the Phillips recess.

The data does not show any significant differences in end load between the removal and installation of fasteners. The average and maximum values are consistent.

TABLE 16

FIELD TORQUE VALUES

Removal

Size	Phillips	Hi-Torque	Torq-Set	Hex	Mean/Max
	Style Fastener				
3/16 shear		22.5/42	19.4/44		21.7/44
3/16 tension	23.1/85	26.5/78	25.9/70		24.6/85
1/4 shear		46.2/124	23.7/86		31.2/124
1/4 tension	56/134		43.2/105		51.5/134

Installation

Size	Phillips	Hi-Torque	Torq-Set	Hex	Mean/Max
3/16 shear		38.5/66	26.1/52		35.3/66
3/16 tension	37.7/80	36/88	43.2/90		38.8/90
1/4 shear		47.7/92	38.6/76		41.6/92
1/4 tension	51.4/128		55.9/104		52.4/128

All values in inch pounds; Average/Maximum.

TABLE 17

FIELD END LOAD VALUES

Removal

Size	Style Fastener				Mean/Max
	Phillips	Hi-Torque	Torq-Set	Hex	
3/16 shear		34.6/92	37.2/95		35.2/95
3/16 tension	39.9/120	41/145	26.6/105		36.7/145
1/4 shear		43.5/102	41.4/100		42.2/102
1/4 tension	56.7/116		24.5/42		47.3/116

Installation

3/16 shear		31.3/64	44/90		34.4/90
3/16 tension	39.8/90	35.4/112	29.5/65		35.9/112
1/4 shear		35/84	43.9/91		40.5/91
1/4 tension	50.7/93		26.2/40		42.0/93

All values in pounds; Average/Maximum.

Field Angle Values

The field measured tool angle data is summarized in Table 18. Previously, the off-set angle was visually observed to be present; but just how large the angles were and what the effect was on torque capability was not known. The maximum values were as high as expected, but the averages were slightly lower than expected, There was not apparent correlation between peak torque and maximum off-set angle; the maximum angle normally occurred somewhere else in the installation or removal cycle.

The Torq-Set and Phillips recesses consistently exhibited higher average off angles than the Hi-Torque recess. While both are capable of large off angles as exhibited by their maximum values, the style itself may play a part. The Hi-Torque recess is a slot with an undercut. This feature may help the mechanic in maintaining a vertical alignment. The Phillips and Torq-Set recesses having a cruciform shape with sloping sides may allow off angles to more naturally occur.

Influence of Panel Orientation

The data was also correlated by the panel orientation, i.e., up, overhead, horizontal, and down. This data is summarized in Table 19. The data is surprisingly consistent. The one noticeable parameter that is noteworthy is the average horizontal end load. It is consistently lower for both removals and installations. This can be accounted for by noting that the mechanic is able to gain leverage in the Up and Down positions. In the Up position, the mechanic's own weight can be applied. With nothing to use as leverage in the horizontal direction, the end load tended to be lower.

Influence of Personnel Size

The effect of personnel size was also determined. This data is shown in Table 20. The data is again consistent with one item being worthy of note. The end load values for those under 130 pounds was less for both the average and maximum values. Apparently, the heavier mechanics took advantage of their weight in applying end load. This is also shown by the consistent increase in average end load with weight of the mechanics.

Influence of Experience

The influence of experience as represented by the field data is shown in Table 21. It confirms what we intuitively have known. Experience helps the mechanic do a better job. Those with less than one year experience averaged lower end loads and higher average off angles.

TABLE 18

FIELD ANGLE VALUES

Removal

Size	Phillips	Hi-Torque	Torq-Set	Hex	Mean/Max
3/16 shear		3.2/22	3.5/8.5		3.2/22
3/16 tension	3.9/15	3.0/13.5	3.5/15		3.6/15
1/4 shear		2.4/8	5.6/16.5		4.6/16.5
1/4 tension	3.9/13.5		3.1/20		3.7/20

Installation

Size	Phillips	Hi-Torque	Torq-Set	Hex	Mean/Max
3/16 shear		2.8/9.5	3.2/8.5		2.9/9.5
3/16 tension	3.6/13.5	2.8/12.0	3.4/11.5		3.4/13.5
1/4 shear		2.3/8.5	5.1/15.5		4.2/15.5
1/4 tension	3.1/14.5		2.8/6		3.1/14.5

All Values in degrees; Average/Maximum

TABLE 19

INFLUENCE OF PANEL ORIENTATION

Size Fastener: 3/16 Tension Head

Removal	UP	HORIZONTAL	DOWN
Torque (in.lbs)	25.6/85	25.6/78	22.7/83
End Load (lb)	40.3/120	31.3/145	39.4/106
Angle (degrees)	3.8/15	3.4/15	3.8/14.5
Installation			
Torque (in. lbs)	32.9/80	40.8/88	41.6/90
End Load (lbs)	36.4/90	31.3/112	40.4/81
Angle (degrees)	3.5/11.5	3.0/13.5	3.6/13

All values are given as Average/Maximum

TABLE 20

INFLUENCE OF PERSONNEL SIZE

Size Fastener: 3/16 Tension Head

Removal			
	>130 lbs	130-165 lbs	< 165 lbs
Torque (in. lbs)	25.2/70	24.8/85	23.5/83
End Load (lbs)	26/64	38.9/145	46.7/110
Angle (degrees)	3.96/15	3.7/13.5	3.2/14.5
Installation			
Torque (in.lbs)	42.6/90	36.8/88	36.9/75
End Load (lbs)	29.1/65	37.4/112	42.5/90
Angle (degrees)	3.6/13	3.5/12	2.98/13.5

All values given as Average/Maximum.

TABLE 21

INFLUENCE OF EXPERIENCE

Size Fastener: 3/16 Tension Head

Removal

	0-1 Years (.19 avg)	1-10 Years (4.44 avg)	10 + Years (18.4 avg)
Torque (in. lbs)	23.8/61	23.6/83	27.1/85
End Load (lbs)	31.1/106	38.1/105	40.82/145
Angle (degrees)	4.6/15	3.1/14.5	3.4/11

Installation

	0-1 Years (.19 avg)	1-10 Years (4.44 avg)	10 + Years (18.4 avg)
Torque (in. lbs)	40.5/90	36.9/80	39.7/88
End Load (lbs)	32.3/65	39.9/90	34.2/112
Angle (degrees)	4.0/13	3.9/13.5	3.3/12

All values given as Average/Maximum.

SECTION VI

CONCLUSIONS/RECOMMENDATIONS

This report has presented the results of four efforts aimed at increasing our fundamental knowledge about recess performance, design, and the imposed field conditions. Some of the data has raised more questions than answers. An important first step was taken to bring recess design within the grasp of analytical methods.

The most significant result is the establishment of a test method for measuring recess performance and the effects of various parameters on this performance that is related to service experience. The results presented in Section II show that the parameters of paint, off angle, undersize drivers, and soft drivers all have adverse effects on recess torque capability. The results also show that the differences in performance between recess styles can also be determined. This test can now help in the selection of a style based on test data as opposed to bias, emotion, or lowest cost. This test by itself cannot choose a style. The tension strength and fatigue strength of the fastener must also be considered in making a final selection.

The test to determine removal-installation torque ratio did not yield all of the desired results. The effects of size, corrosion, torque levels, and sealant were not clearly demonstrated. The most significant result is that cadmium plated alloy fasteners used with cadmium plated nuts will yield higher removal torques than stainless steel fasteners.

Additional testing is necessary in order to determine the parameters that affect the constants C1 and C2. The type of recess, the dimensions of the recess, and the material and manufacturing processes can significantly affect the constants C1 and C2. An adequate test program is necessary to study these aspects of the empirical analysis.

As was mentioned at the outset of Section IV, the present analysis is only adequate for determining static strength and for determining the optimum recess dimensions in a preliminary design. However, for service life estimate and crack initiation and propagation studies, knowledge of the detailed stress distribution and stress concentration effects is necessary. A finite element analysis or a similar approach is suitable for this study.

The field data contained many surprises. The reason for the skew in the data is not known. The relatively low removal torque values was unsuspected as the removal-installation torque ratios were thought to be greater than one.

In spite of some differences, due to panel orientation, personnel size and experience, the data was remarkably consistent.

If the field data indeed reflects the real world imposed conditions, then one should not be too eager to place the primary cause for field problems to the mechanic. Certainly, field abuse does take place. But the data shows that fasteners are not being routinely overtorqued or subjected to overly harsh conditions. Then the design of the recess itself becomes the primary focus. A recess design that limits the maximum installation torque becomes a desirable feature. It should also have more removal torque capability than installation torque to insure removal of the fastener. It should be damage tolerant. That is, when an overtorque condition is imposed, it should not lose significant percentage of its torque capability. Our tests did not reveal a recess design with these characteristics.

As with any initial endeavor, follow-on tests immediately become visible. Some of these are:

a. verification of the analytical model for fastener tension strength

b. determination of fastener fatigue characteristics as a function of recess depth

c. investigation of alternative test procedures to determine the effect of various parameters on the removal torque

d. getting a data base on recess performance for larger fastener sizes and other materials.

APPENDIX A

TEST RESULTS/RECESS FASTENER TEST METHOD

Recess Fastener List of Laboratory Results

Data Column Identification

A. Test Matrix Identification - See Table 2
B. Recess Style
C. Test Replicate Number
D. T Signifies Tension Head
E. Size of Fastener: 3 = 3/16" diameter
F. Paint Condition: N = No Paint, Y = Paint
G. Driver Angle in Degrees
H. N Signifies New Driver
I. Driver Hardness: H = Hard Driver; S = Soft Driver
J. Driver Size: C = Correct Size; U = Undersize Driver
K. End Load in Lbs
L. Measured Torque at First Failure in in.lbs.
M. Subjective Evaluation of Recess Condition: RF = Recess Fair Condition; RN = Recess No Damage; RW = Recess Worn
N. Subjective Evaluation of Bit Condition: BN = Bit No Wear; BB = Bit Broken; BF = Bit Fair
O. The Y Indicates a Failure Occurred
P. End Load for Second Failure Determination in lbs
Q. Measured Torque at Second Failure in in. lbs.
R. Subjective Evaluation of Recess Condition
S. Subjective Evaluation of Bit Condition
T. The Y Indicates a Failure Occurred

RECESS FASTENER LIST OF LABORATORY RESULTS

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
01	A	1	T	3	N	C	N	H	C	1.3	91	RF	BN	Y	10	46	RW	BN	Y
01	A	2	T	3	N	C	N	H	C	1.3	94	PF	3N	Y	20	54	RW	9N	Y
01	A	3	T	3	N	C	N	H	C	1.3	96	RF	BN	Y					
01	A	4	T	3	N	C	N	H	C	1.3	97	PF	3N	Y					
01	A	1	T	3	N	C	N	H	C	5	97	PF	3N	Y	10	40	RW	9N	Y
01	A	2	T	3	N	C	N	H	C	5	93	RF	3N	Y	20	59	RW	BN	Y
01	A	3	T	3	N	C	N	H	C	5	94	PF	BN	Y	40	77	RW	3N	Y
01	A	4	T	3	N	C	N	H	C	5	92	PF	3N	Y					
01	A	1	T	3	N	C	N	H	C	10	100	RF	9N	Y	10	37	RW	BN	Y
01	A	2	T	3	N	C	N	H	C	10	100	PF	3N	Y	20	50	RW	3N	Y
01	A	3	T	3	N	C	N	H	C	10	96	PF	3N	Y	40	73	RW	9N	Y
01	A	4	T	3	N	C	N	H	C	10	93	RF	3N	Y	60	69	RW	9N	Y
01	A	1	T	3	N	C	N	H	C	20	101	PF	3N	Y	10	35	RW	9N	Y
01	A	2	T	3	N	C	N	H	C	20	99	RF	3N	Y	20	32	RW	BN	Y
01	A	3	T	3	N	C	N	H	C	20	100	RF	BN	Y	40	55	RW	BN	Y
01	A	4	T	3	N	C	N	H	C	20	103	RF	3N	Y	60	74	RW	3N	Y
02	A	1	T	3	N	7	N	H	C	1.3	71	PF	3N	Y	10	25	PF	3N	Y
02	A	2	T	3	N	7	N	H	C	1.3	68	RF	3N	Y	20	34	PF	3N	Y
02	A	3	T	3	N	7	N	H	C	1.3	66	RF	3N	Y	40	12	RF	9N	Y
02	A	4	T	3	N	7	N	H	C	1.3	60	PF	3N	Y	60	20	RW	9N	Y
02	A	1	T	3	N	7	N	H	C	5	63	PF	3N	Y	10	5	PW	3N	Y
02	A	2	T	3	N	7	N	H	C	5	71	RF	3N	Y	20	12	PW	9N	Y
02	A	3	T	3	N	7	N	H	C	5	63	RF	3N	Y	40	11	RW	BN	Y
02	A	4	T	3	N	7	N	H	C	5	59	PF	3N	Y	60	15	RW	9N	Y
02	A	1	T	3	N	7	N	H	C	10	53	RF	3N	Y	10	9	PW	3N	Y
02	A	2	T	3	N	7	N	H	C	10	72	RF	3N	Y	20	19	RW	3N	Y
02	A	3	T	3	N	7	N	H	C	10	71	PF	3N	Y	40	19	RW	3N	Y
02	A	4	T	3	N	7	N	H	C	10	71	RF	3N	Y	60	29	RW	9N	Y
02	A	1	T	3	N	7	N	H	C	20	76	PF	3N	Y	10	16	PW	3N	Y
02	A	2	T	3	N	7	N	H	C	20	36	RF	3N	Y	20	9	PW	9N	Y
02	A	3	T	3	N	7	N	H	C	20	78	RF	3N	Y	40	22	RW	3N	Y
02	A	4	T	3	N	7	N	H	C	20	74	RF	3N	Y	60	23	RW	3N	Y
03	A	1	T	3	N	C	N	H	U	1.3	59	PF	3N	Y	10	5	RF	9N	Y
03	A	2	T	3	N	C	N	H	U	1.3	52	PF	3N	Y	20	17	RF	9N	Y
03	A	3	T	3	N	C	N	H	U	1.3	52	PF	3N	Y	40	37	PW	3N	Y
03	A	4	T	3	N	C	N	H	U	1.3	55	PF	3N	Y	60	45	PW	3N	Y
03	A	1	T	3	N	C	N	H	U	5	58	PF	3N	Y	10	10	RW	3N	Y
03	A	2	T	3	N	C	N	H	U	5	62	RF	3N	Y	20	15	PW	3N	Y
03	A	3	T	3	N	C	N	H	U	5	50	PF	3N	Y	40	47	RW	3N	Y
03	A	4	T	3	N	C	N	H	U	5	53	PF	3N	Y	60	37	RW	9N	Y
03	A	1	T	3	N	C	N	H	U	10	51	PF	3N	Y	10	39	PW	3N	Y
03	A	2	T	3	N	C	N	H	U	10	56	PF	3N	Y	20	19	RW	9N	Y
03	A	3	T	3	N	C	N	H	U	10	63	PF	3N	Y	40	41	PW	3N	Y

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03	A	4	T	3	N	C	N	H	U	10	57	RF	3N	Y	60	35	RW	9N	Y
03	A	1	T	3	N	L	N	H	U	20	58	RF	3N	Y	10	27	RW	3N	Y
03	A	2	T	3	N	L	N	H	U	20	59	RF	3N	Y	20	31	RW	9N	Y
03	A	3	T	3	N	L	N	H	U	20	65	RF	3N	Y	40	25	RW	BN	Y
03	A	4	T	3	N	L	N	H	U	20	61	RF	3N	Y	60	44	RW	BN	Y
04	A	1	T	3	N	7	N	H	U	1.3	57	RF	3N	Y	10	19	RF	BN	Y
04	A	2	T	3	N	7	N	H	U	1.3	49	RF	3N	Y	20	12	RF	3N	Y
04	A	3	T	3	N	7	N	H	U	1.3	53	RF	3N	Y	40	19	RW	9N	Y
04	A	4	T	3	N	7	N	H	U	1.3	53	RF	3N	Y	60	12	RW	9N	Y
04	A	1	T	3	N	7	N	H	U	5	57	RF	9N	Y	10	8	RW	3N	Y
04	A	2	T	3	N	7	N	H	U	5	61	RF	3N	Y	20	11	RW	BN	Y
04	A	3	T	3	N	7	N	H	U	5	59	RF	3N	Y	40	13	RW	3N	Y
04	A	4	T	3	N	7	N	H	U	5	56	RF	3N	Y	60	17	RW	9N	Y
04	A	1	T	3	N	7	N	H	U	10	52	RF	3N	Y	10	3	RW	3N	Y
04	A	2	T	3	N	7	N	H	U	10	55	RF	3N	Y	20	6	RW	9N	Y
04	A	3	T	3	N	7	N	H	U	10	60	RF	3N	Y	40	7	RW	9N	Y
04	A	4	T	3	N	7	N	H	U	10	57	RF	3N	Y	60	32	RW	3N	Y
04	A	1	T	3	N	7	N	H	U	20	54	RF	3N	Y	10	3	RW	9N	Y
04	A	2	T	3	N	7	N	H	U	20	56	RF	3N	Y	20	8	RW	9N	Y
04	A	3	T	3	N	7	N	H	U	20	64	RF	3N	Y	40	9	RW	3N	Y
04	A	4	T	3	N	7	N	H	U	20	63	RF	9N	Y	60	47	RW	9N	Y
05	A	1	T	3	N	C	N	S	C	1.3	61	RN	39	Y	20	58	RN	39	Y
05	A	2	T	3	N	L	N	S	C	1.3	60	RN	39	Y	60	61	RN	89	Y
05	A	1	T	3	N	C	N	S	C	5	62	RN	39	Y	20	58	RN	39	Y
05	A	2	T	3	N	L	N	S	C	5	57	RN	89	Y	60	62	RN	39	Y
05	A	1	T	3	N	C	N	S	C	10	62	RN	39	Y	20	58	RN	39	Y
05	A	2	T	3	N	C	N	S	C	10	64	RN	39	Y	60	62	RN	89	Y
05	A	1	T	3	N	L	N	S	C	20	64	RN	39	Y	20	59	RN	39	Y
05	A	2	T	3	N	C	N	S	C	20	65	RN	89	Y	60	63	RN	99	Y
06	A	1	T	3	N	7	N	S	C	1.3	46	RN	39	Y	20	41	RN	99	Y
06	A	2	T	3	N	7	N	S	C	1.3	40	RN	39	Y	60	47	RN	89	Y
06	A	1	T	3	N	7	N	S	C	5	42	RN	39	Y					
06	A	2	T	3	N	7	N	S	C	5	42	RN	39	Y	60	45	RN	39	Y
06	A	2	T	3	N	7	N	S	C	10	49	RN	39	Y					
06	A	2	T	3	N	7	N	S	C	10	44	RN	39	Y	60	46	RN	39	Y
06	A	1	T	3	N	7	N	S	C	20	46	RN	99	Y	20	39	RN	99	Y
06	A	2	T	3	N	7	N	S	C	20	51	RN	39	Y	60	49	RN	99	Y
07	A	1	T	3	N	C	N	S	U	1.3	38	RN	3F	Y	10	12	RN	3W	Y
07	A	2	T	3	N	C	N	S	U	1.3	34	RN	3F	Y	20	22	RN	9W	Y
07	A	3	T	3	N	C	N	S	U	1.3	35	RN	3F	Y	40	24	RN	3W	Y
07	A	4	T	3	N	C	N	S	U	1.3	36	RN	3F	Y	60	32	RN	9W	Y
07	A	1	T	3	N	L	N	S	U	5	39	RN	3W	Y	10	7	RN	9W	Y
07	A	2	T	3	N	L	N	S	U	5	38	RN	3W	Y	20	10	RN	3W	Y
07	A	3	T	3	N	C	N	S	U	5	38	RN	9W	Y	40	16	RN	3W	Y
07	A	4	T	3	N	L	N	S	U	5	41	RN	3W	Y	60	19	RN	3W	Y
07	A	1	T	3	N	L	N	S	U	10	39	RN	3W	Y	10	5	RN	9W	Y
07	A	2	T	3	N	C	N	S	U	10	41	RN	3W	Y	20	27	RN	9W	Y
07	A	3	T	3	N	C	N	S	U	10	40	RN	3W	Y	60	15	RN	3W	Y
07	A	1	T	3	N	L	N	S	U	20	43	RN	9W	Y	10	2	RN	9W	Y
07	A	2	T	3	N	L	N	S	U	20	43	RN	3W	Y	20	25	RN	3W	Y
07	A	3	T	3	N	L	N	S	U	20	42	RN	3W	Y	60	23	RN	9W	Y
07	A	4	T	3	N	C	N	S	U	20	42	RN	3W	Y	60	41	RN	3W	Y
08	A	1	T	3	N	7	N	S	U	1.3	32	RN	9W	Y	20	34	RF	3W	Y
08	A	2	T	3	N	7	N	S	U	1.3	32	RN	3W	Y	60	36	RF	9W	Y
08	A	1	T	3	N	7	N	S	U	5	33	RN	3W	Y	20	13	RF	9W	Y
08	A	2	T	3	N	7	N	S	U	5	36	RN	3W	Y	60	34	RF	9W	Y

08	A	1	T	3	N	7	N	S	U	10	35	RN	3W	Y	20	1[illegible]	RF	3W	Y
08	A	2	T	3	N	7	N	S	U	10	37	RN	3W	Y	60	38	RF	3W	Y
08	A	1	T	3	N	7	N	S	U	20	38	RN	3W	Y	20	23	RF	3W	Y
08	A	2	T	3	N	7	N	S	U	20	38	RN	3W	Y	60	40	RF	3W	Y
17	A	1	T	3	Y	C	N	H	C	1.3	75	RF	3N	Y	10	30	RF	3N	Y
17	A	2	T	3	Y	C	N	H	C	1.3	67	RF	3N	Y	20	50	RF	3N	Y
17	A	3	T	3	Y	C	N	H	C	1.3	71	RF	3N	Y	40	52	RF	3N	Y
17	A	4	T	3	Y	C	N	H	C	1.3	75	RF	3N	Y	60	78	RF	3N	Y
17	A	1	T	3	Y	C	N	H	C	5	70	RF	3N	Y	10	52	RF	3N	Y
17	A	2	T	3	Y	C	N	H	C	5	72	RF	3N	Y	20	44	RF	3N	Y
17	A	3	T	3	Y	C	N	H	C	5	75	RF	3N	Y	40	66	RF	3N	Y
17	A	4	T	3	Y	C	N	H	C	5	72	RF	3N	Y	60	72	RF	3N	Y
17	A	1	T	3	Y	C	N	H	C	10	78	RF	3N	Y	10	59	RF	3N	Y
17	A	2	T	3	Y	C	N	H	C	10	76	RF	3N	Y	20	50	RF	3N	Y
17	A	3	T	3	Y	C	N	H	C	10	76	RF	3N	Y	40	55	RF	3N	Y
17	A	4	T	3	Y	C	N	H	C	10	73	RF	3N	Y	60	61	RF	3N	Y
17	A	1	T	3	Y	C	N	H	C	20	82	RF	3N	Y	10	27	RF	3N	Y
17	A	2	T	3	Y	C	N	H	C	20	95	RF	3N	Y	20	41	RF	3N	Y
17	A	3	T	3	Y	C	N	H	C	20	77	RF	3N	Y	40	33	RF	3N	Y
17	A	4	T	3	Y	C	N	H	C	20	8[illegible]	RF	3N	Y	60	62	RF	3N	Y
18	A	1	T	3	Y	7	N	H	C	1.3	43	RF	3N	Y	10	22	RW	3N	Y
18	A	2	T	3	Y	7	N	H	C	1.3	51	RF	3N	Y	20	19	RW	3N	Y
18	A	4	T	3	Y	7	N	H	C	1.3	5[illegible]	RF	3N	Y	40	25	RW	3N	Y
18	A	3	T	3	Y	7	N	H	C	1.3	51	RF	3N	Y	60	43	RW	3N	Y
18	A	1	T	3	Y	7	N	H	C	5	53	RF	3N	Y	10	14	RW	3N	Y
18	A	2	T	3	Y	7	N	H	C	5	47	RF	3N	Y	20	21	RW	3N	Y
18	A	4	T	3	Y	7	N	H	C	5	53	RF	3N	Y	40	51	RW	3N	Y
18	A	3	T	3	Y	7	N	H	C	5	58	RF	3N	Y	60	22	RW	3N	Y
18	A	1	T	3	Y	7	N	H	C	10	54	RF	3N	Y	10	8	RW	3N	Y
18	A	2	T	3	Y	7	N	H	C	10	57	RF	3N	Y	20	3	RW	3N	Y
18	A	4	T	3	Y	7	N	H	C	10	57	RF	3N	Y	40	33	RW	3N	Y
18	A	3	T	3	Y	7	N	H	C	10	49	RF	3N	Y	60	25	RW	3N	Y
18	A	1	T	3	Y	7	N	H	C	20	50	RF	3N	Y	10	18	RW	3N	Y
18	A	2	T	3	Y	7	N	H	C	20	63	RF	3N	Y	20	13	RW	3N	Y
18	A	3	T	3	Y	7	N	H	C	20	58	RF	3N	Y	60	25	RW	3N	Y
18	A	4	T	3	Y	7	N	H	C	20	56	RF	3N	Y	40	29	RW	3N	Y
19	A	4	T	3	Y	C	N	H	U	1.3	36	RW	3F	Y					
19	A	1	T	3	Y	C	N	H	U	1.3	4[illegible]	RW	3F	Y	10	15	RW	3F	Y
19	A	2	T	3	Y	C	N	H	U	1.3	39	RW	3F	Y	20	36	RW	3F	Y
19	A	3	T	3	Y	C	N	H	U	1.3	41	RW	3F	Y	60	49	RW	3F	Y
19	A	1	T	3	Y	C	N	H	U	5	48	RW	3F	Y					
19	A	4	T	3	Y	C	N	H	U	5	45	RW	3F	Y	40	45	RW	3F	Y
19	A	2	T	3	Y	C	N	H	U	5	44	RW	3F	Y	20	28	RW	3F	Y
19	A	3	T	3	Y	C	N	H	U	5	45	RW	3F	Y	60	52	RW	3F	Y
19	A	1	T	3	Y	C	N	H	U	10	52	RW	3F	Y	10	29	RW	3F	Y
19	A	4	T	3	Y	C	N	H	U	10	52	RW	3F	Y	40	52	RW	3F	Y
19	A	2	T	3	Y	C	N	H	U	10	48	RW	3F	Y	20	32	RW	3F	Y
19	A	3	T	3	Y	C	N	H	U	10	52	RW	3F	Y					
19	A	1	T	3	Y	C	N	H	U	20	53	RW	3F	Y	10	25	RW	3F	Y
19	A	2	T	3	Y	C	N	H	U	20	50	RW	3F	Y					
19	A	3	T	3	Y	C	N	H	U	20	55	RW	3F	Y	60	50	RW	3F	Y
19	A	4	T	3	Y	C	N	H	U	20	52	RW	3F	Y	40	32	RW	3F	Y
20	A	1	T	3	Y	7	N	H	U	1.3	37	RF	3N	Y	10	[illegible]	RF	3N	Y
20	A	2	T	3	Y	7	N	H	U	1.3	41	RF	3N	Y	20	23	RF	3N	Y
20	A	3	T	3	Y	7	N	H	U	1.3	39	RF	3N	Y	60	37	RF	3N	Y
20	A	1	T	3	Y	7	N	H	U	5	41	RF	3N	Y	10	13	RF	3N	Y

20	A	2	T	3	Y	7	N	H	U	5	47	RF	BN	Y	20	8	RF	BN	Y
20	A	4	T	3	Y	7	N	H	U	5	41	RF	BN	Y	40	9	RF	BN	Y
20	A	3	T	3	Y	7	N	H	U	5	44	RF	BN	Y	60	35	RF	BN	Y
20	A	1	T	3	Y	7	N	H	U	10	47	RF	BN	Y	10	5	RF	BN	Y
20	A	2	T	3	Y	7	N	H	U	10	47	RF	BN	Y	20	29	RF	BN	Y
20	A	4	T	3	Y	7	N	H	U	10	47	RF	BN	Y	40	43	RF	BN	Y
20	A	3	T	3	Y	7	N	H	U	10	48	RF	BN	Y	60	34	RF	BN	Y
20	A	1	T	3	Y	7	N	H	U	20	50	RF	BN	Y	10	3	RF	BN	Y
20	A	2	T	3	Y	7	N	H	U	20	56	RF	BN	Y	20	23	RF	BN	Y
20	A	4	T	3	Y	7	N	H	U	20	50	RF	BN	Y	40	7	RF	BN	Y
20	A	3	T	3	Y	7	N	H	U	20	51	RF	BN	Y	60	25	RF	BN	Y
21	A	4	T	3	Y	0	N	S	C	1.3	48	RN	BF	Y	40	15	RN	BW	Y
21	A	1	T	3	Y	0	N	S	C	1.3	48	RN	BF	Y	10	33	RN	BW	Y
21	A	2	T	3	Y	0	N	S	C	1.3	49	RN	BF	Y	20	33	RN	BW	Y
21	A	3	T	3	Y	0	N	S	C	1.3	45	RN	BF	Y	60	39	RW	BW	Y
21	A	1	T	3	Y	0	N	S	C	5	52	RN	BF	Y	10	34	RN	BW	Y
21	A	4	T	3	Y	0	N	S	C	5	52	RN	BF	Y	40	36	RN	BW	Y
21	A	2	T	3	Y	0	N	S	C	5	50	RN	BF	Y	20	35	RN	BW	Y
21	A	3	T	3	Y	0	N	S	C	5	49	RN	BF	Y	60	33	RN	BW	Y
21	A	1	T	3	Y	0	N	S	C	10	48	RN	BF	Y	10	39	RN	BW	Y
21	A	2	T	3	Y	0	N	S	C	10	46	RN	BF	Y	20	36	RN	BW	Y
21	A	4	T	3	Y	0	N	S	C	10	51	RN	BF	Y	40	14	RN	BW	Y
21	A	3	T	3	Y	0	N	S	C	10	50	RN	BF	Y	60	40	RN	BW	Y
21	A	1	T	3	Y	0	N	S	C	20	54	RN	BF	Y	10	30	RN	BW	Y
21	A	2	T	3	Y	0	N	S	C	20	53	RN	BF	Y	20	41	RW	BW	Y
21	A	3	T	3	Y	0	N	S	C	20	54	RN	BF	Y	60	33	RW	BW	Y
21	A	4	T	3	Y	0	N	S	C	20	52	RN	BF	Y	40	41	RW	BW	Y
22	A	2	T	3	Y	7	N	S	C	1.3	32	RN	BB	Y	20	41	RN	BB	Y
22	A	3	T	3	Y	7	N	S	C	1.3	34	RN	BB	Y	60	45	RN	BB	Y
22	A	2	T	3	Y	7	N	S	C	5	36	RN	BB	Y	20	41	RN	BB	Y
22	A	3	T	3	Y	7	N	S	C	5	40	RN	BB	Y	60	49	RN	BB	Y
22	A	2	T	3	Y	7	N	S	C	10	41	RN	BB	Y	20	47	RN	BB	Y
22	A	3	T	3	Y	7	N	S	C	10	39	RN	BB	Y	60	44	RN	BB	Y
22	A	2	T	3	Y	7	N	S	C	20	40	RN	BB	Y	20	41	RN	BB	Y
22	A	3	T	3	Y	7	N	S	C	20	40	RN	BB	Y	60	46	RN	BB	Y
23	A	1	T	3	Y	0	N	S	U	1.3	30	RN	BB	Y	10	31	RN	BB	Y
23	A	2	T	3	Y	0	N	S	U	1.3	32	RN	BB	Y					
23	A	3	T	3	Y	0	N	S	U	1.3	31	RN	BB	Y					
23	A	1	T	3	Y	0	N	S	U	5	33	RN	BB	Y					
23	A	2	T	3	Y	0	N	S	U	5	32	RN	BB	Y	20	35	RN	BB	Y
23	A	3	T	3	Y	0	N	S	U	5	34	RN	BB	Y					
23	A	1	T	3	Y	0	N	S	U	10	35	RN	BB	Y					
23	A	2	T	3	Y	0	N	S	U	10	35	RN	BB	Y					
23	A	3	T	3	Y	0	N	S	U	10	35	RN	BB	Y					
23	A	1	T	3	Y	0	N	S	U	20	36	RN	BB	Y					
23	A	2	T	3	Y	0	N	S	U	20	33	RN	BB	Y					
23	A	3	T	3	Y	0	N	S	U	20	39	RN	BB	Y	60	40	RN	BB	Y
24	A	1	T	3	Y	7	N	S	U	1.3	22	RN	BB	Y					
24	A	2	T	3	Y	7	N	S	U	1.3	30	RN	BB	Y	20	33	RN	BB	Y
24	A	1	T	3	Y	7	N	S	U	5	32	RN	BB	Y					
24	A	2	T	3	Y	7	N	S	U	5	30	RN	BB	Y	60	33	RN	BB	Y
24	A	1	T	3	Y	7	N	S	U	10	32	RN	BB	Y					
24	A	2	T	3	Y	7	N	S	U	10	34	RN	BB	Y	60	36	RN	BB	Y
24	A	1	T	3	Y	7	N	S	U	20	35	RN	BB	Y					
24	A	2	T	3	Y	7	N	S	U	20	34	RN	BB	Y	60	37	RN	BB	Y

01	B	1	T	3	N	C	N	H	C	1.3	103	RN	3B	Y	10	89	RN	3N	N
01	B	2	T	3	N	C	N	H	C	1.3	103	RN	3B	Y	20	92	RN	9N	N
01	B	3	T	3	N	C	N	H	C	1.3	102	RN	3B	Y	60	95	RN	3N	N
01	B	1	T	3	N	C	N	H	C	5	103	RN	9B	Y	10	90	RN	BN	N
01	B	2	T	3	N	C	N	H	C	5	104	RN	3B	Y	20	84	RN	3N	N
01	B	3	T	3	N	C	N	H	C	5	104	RN	33	Y	60	97	RN	9N	N
01	B	1	T	3	N	C	N	H	C	10	102	RN	33	Y	10	92	RN	3N	N
01	B	2	T	3	N	C	N	H	C	10	102	RN	93	Y	20	99	RN	3N	N
01	B	3	T	3	N	C	N	H	C	10	102	RN	39	Y	60	93	RN	9N	N
01	B	1	T	3	N	0	N	H	C	20	105	RN	39	Y	10	98	RN	9N	N
01	B	2	T	3	N	C	N	H	C	20	103	RN	93	Y	20	93	RN	3N	N
01	B	3	T	3	N	C	N	H	C	20	103	RN	83	Y	60	97	RN	BN	N
02	B	1	T	3	N	7	N	H	C	1.3	95	RF	3W	Y	60	59	RF	9W	Y
02	B	1	T	3	N	7	N	H	C	5	103	RF	3W	Y	20	31	RF	9W	Y
02	B	1	T	3	N	7	N	H	C	20	104	RF	3W	Y	60	33	RF	9W	Y
02	B	2	T	3	N	7	N	H	C	20	104	RF	39	Y	60	29	RF	RW	Y
02	B	3	T	3	N	7	N	H	C	20	101	RF	9W	Y	20	38	RF	9W	Y
03	B	1	T	3	N	C	N	H	U	1.3	59	RF	3N	Y	10	9	RF	9N	Y
03	B	2	T	3	N	C	N	H	U	1.3	57	RF	3N	Y	20	9	RF	3N	Y
03	B	3	T	3	N	C	N	H	U	1.3	56	RF	3N	Y	60	14	RF	9N	Y
03	B	1	T	3	N	C	N	H	U	5	55	RF	9N	Y	10	9	9F	3N	Y
03	B	2	T	3	N	C	N	H	U	5	59	RF	3N	Y	20	10	3F	3N	Y
03	B	3	T	3	N	C	N	H	U	5	57	RF	3N	Y	60	13	8F	3N	Y
03	B	1	T	3	N	C	N	H	U	10	55	RF	3N	Y	10	7	RF	3N	Y
03	B	2	T	3	N	C	N	H	U	10	57	RF	3N	Y	20	7	8F	3N	Y
03	B	3	T	3	N	C	N	H	U	10	59	RF	3N	Y	60	9	9F	3N	Y
03	B	1	T	3	N	C	N	H	U	20	56	RF	9N	Y	10	8	RF	9N	Y
03	B	2	T	3	N	C	N	H	U	20	55	RF	3N	Y	20	4	RF	RN	Y
03	B	3	T	3	N	C	N	H	U	20	57	RF	3N	Y	60	9	RF	9N	Y
04	B	1	T	3	N	7	N	H	U	1.3	45	RF	9N	Y	10	8	RF	3N	Y
04	B	2	T	3	N	7	N	H	U	1.3	47	RF	9N	Y	20	17	RF	9N	Y
04	B	3	T	3	N	7	N	H	U	1.3	45	RF	9N	Y	60	15	RF	3N	Y
04	B	1	T	3	N	7	N	H	U	5	45	RF	3N	Y	10	12	RF	9N	Y
04	B	2	T	3	N	7	N	H	U	5	47	RF	9N	Y	20	16	RF	RN	Y
04	B	3	T	3	N	7	N	H	U	5	47	RF	3N	Y	60	13	RF	3N	Y
04	B	1	T	3	N	7	N	H	U	10	53	RF	3N	Y	10	7	RF	RN	Y
04	B	2	T	3	N	7	N	H	U	10	49	RF	3N	Y	20	17	RF	9N	Y
04	B	3	T	3	N	7	N	H	U	10	51	RF	3N	Y	60	13	RF	9N	Y
04	B	1	T	3	N	7	N	H	U	20	51	RF	3N	Y	10	13	RF	3N	Y
04	B	2	T	3	N	7	N	H	U	20	52	RF	3N	Y	20	9	RF	3N	Y
04	B	3	T	3	N	7	N	H	U	20	47	RF	3N	Y	60	21	RF	9N	Y
05	B	1	T	3	N	C	N	S	C	1.3	53	RN	93	Y	10	55	RN	3N	N
05	B	2	T	3	N	C	N	S	C	1.3	57	RN	39	Y	20	55	RN	3N	N
05	B	3	T	3	N	C	N	S	C	1.3	57	RN	39	Y	60	59	RN	9N	N
05	B	1	T	3	N	C	N	S	C	20	67	RN	39	Y	10	53	RN	3N	N
05	B	2	T	3	N	C	N	S	C	20	59	RN	33	Y	20	55	RN	3N	N
05	B	3	T	3	N	C	N	S	C	20	57	RN	93	Y	60	53	RN	3N	N
06	B	1	T	3	N	7	N	S	C	1.3	60	RF	39	Y	20	59	RF	9N	N

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06	B	2	T	3	N	7	N	S	C	1.3	63	RF	3B	Y	60	52	RF	3N	N
06	B	1	T	3	N	7	N	S	C	20	64	RF	3B	Y	20	55	RF	BN	N
06	B	2	T	3	N	7	N	S	C	20	64	RF	8B	Y	60	62	RF	BN	N
17	B	1	T	3	Y	C	N	H	C	1.3	103	RN	3B	Y					
17	B	2	T	3	Y	C	N	H	C	1.3	104	RN	3B	Y	60	103	RF	BB	Y
17	B	1	T	3	Y	C	N	H	C	20	106	RR	3B	Y					
17	B	2	T	3	Y	C	N	H	C	20	106	RR	3B	Y					
18	B	1	T	3	Y	7	N	H	C	1.3	84	RF	3N	Y	10	15	RF	3N	Y
18	B	2	T	3	Y	7	N	H	C	1.3	95	RF	3F	Y	60	37	RF	BF	Y
18	B	1	T	3	Y	7	N	H	C	5	94	RF	BN	Y	60	37	RF	BN	Y
16	B	1	T	3	Y	7	N	H	C	10	90	RF	BN	Y	10	5	RF	BN	Y
18	B	2	T	3	Y	7	N	H	C	10	94	RF	3N	Y	60	42	RF	3F	Y
18	B	1	T	3	Y	7	N	H	C	20	97	RF	3F	Y	20	13	RF	3F	Y
18	B	2	T	3	Y	7	N	H	C	20	98	RF	3F	Y	60	32	RF	9F	Y
19	B	1	T	3	Y	C	N	H	U	1.3	56	RF	9N	Y	10	9	RF	3F	Y
19	B	2	T	3	Y	C	N	H	U	1.3	55	RF	3N	Y	20	7	RF	BN	Y
19	B	3	T	3	Y	C	N	H	U	1.3	52	RF	3N	Y	60	11	RF	9N	Y
19	B	1	T	3	Y	C	N	H	U	20	55	RF	3N	Y	10	3	RF	9N	Y
19	B	2	T	3	Y	C	N	H	U	20	47	RF	9N	Y	20	13	RF	3N	Y
19	B	3	T	3	Y	C	N	H	U	20	52	RF	3N	Y	60	11	RF	9N	Y
20	B	1	T	3	Y	7	N	H	U	1.3	43	RF	9F	Y	10	4	RW	3F	Y
20	B	2	T	3	Y	7	N	H	U	1.3	47	RF	3F	Y	20	9	RW	3F	Y
20	B	3	T	3	Y	7	N	H	U	1.3	46	RF	3F	Y	60	17	RW	9F	Y
20	B	1	T	3	Y	7	N	H	U	5	41	RF	BF	Y	10	13	RW	9F	Y
20	B	2	T	3	Y	7	N	H	U	5	50	RF	3F	Y	20	10	RW	8F	Y
20	B	3	T	3	Y	7	N	H	U	5	46	RF	9F	Y	60	14	RW	RF	Y
20	B	1	T	3	Y	7	N	H	U	10	47	RF	3F	Y	10	8	RW	9F	Y
20	B	2	T	3	Y	7	N	H	U	10	43	RF	3F	Y	20	5	RW	9F	Y
20	B	3	T	3	Y	7	N	H	U	10	59	RF	9F	Y	60	12	RW	BF	Y
20	B	1	T	3	Y	7	N	H	U	20	49	RF	9F	Y	10	6	RW	9F	Y
20	B	2	T	3	Y	7	N	H	U	20	46	RF	BF	Y	20	9	RW	9F	Y
20	B	3	T	3	Y	7	N	H	U	20	55	RF	3F	Y	60	13	RW	3F	Y
21	B	2	T	3	Y	C	N	S	C	1.3	69	RN	39	Y	20	65	RN	99	Y
21	B	3	T	3	Y	C	N	S	C	1.3	67	RN	93	Y					
21	B	3	T	3	Y	C	N	S	C	5	68	RN	99	Y					
21	B	3	T	3	Y	C	N	S	C	10	69	RW	9B	Y					
21	B	2	T	3	Y	C	N	S	C	20	69	RW	49	Y					
21	B	3	T	3	Y	C	N	S	C	20	68	RW	49	Y					
22	B	2	T	3	Y	7	N	S	C	1.3	62	PN	33	Y	20	51	RN	93	Y
22	B	3	T	3	Y	7	N	S	C	1.3	59	RN	39	Y	60	53	RN	33	Y
22	B	2	T	3	Y	7	N	S	C	20	62	RN	33	Y	20	58	RN	99	Y
22	B	3	T	3	Y	7	N	S	C	20	62	RN	89	Y	60	53	RN	98	Y

01	C	1	T	3	N	0	N	H	C	1.3	123	RF	BN	Y	10	35	RW	BN	Y
01	C	2	T	3	N	0	N	H	C	1.3	121	RF	BN	Y	20	35	RW	BN	Y
01	C	3	T	3	N	0	N	H	C	1.3	122	RF	BN	Y	60	82	RW	BN	Y
01	C	1	T	3	N	0	N	H	C	5	122	RF	BN	Y	10	41	RW	BN	Y
01	C	2	T	3	N	0	N	H	C	5	125	RF	BN	Y	20	55	RW	BN	Y
01	C	3	T	3	N	0	N	H	C	5	123	RF	BN	Y	60	86	RW	BN	Y
01	C	1	T	3	N	0	N	H	C	10	119	RF	BN	Y	10	11	RW	BN	Y
01	C	2	T	3	N	0	N	H	C	10	123	RF	BN	Y	20	39	RW	BN	Y
01	C	3	T	3	N	0	N	H	C	10	122	RF	BN	Y	60	69	RW	BN	Y
01	C	1	T	3	N	0	N	H	C	20	124	RF	BN	Y	10	30	RW	BN	Y
01	C	2	T	3	N	0	N	H	C	20	126	RF	BN	Y	20	37	RW	BN	Y
01	C	3	T	3	N	0	N	H	C	20	124	RF	BN	Y	60	75	RW	BN	Y
02	C	1	T	3	N	7	N	H	C	1.3	79	RF	BN	Y					
02	C	2	T	3	N	7	N	H	C	1.3	77	RW	BN	Y	20	18	RW	BN	Y
02	C	3	T	3	N	7	N	H	C	1.3	90	RW	BN	Y	60	74	RW	BN	Y
02	C	1	T	3	N	7	N	H	C	5	73	RW	BN	Y	10	33	RW	BN	Y
02	C	2	T	3	N	7	N	H	C	5	80	RW	BN	Y	20	16	RW	BN	Y
02	C	3	T	3	N	7	N	H	C	5	84	RW	BN	Y	60	77	RW	BN	Y
02	C	1	T	3	N	7	N	H	C	10	75	RW	BN	Y	10	48	RW	BN	Y
02	C	2	T	3	N	7	N	H	C	10	93	RW	BN	Y	20	6	RW	BN	Y
02	C	3	T	3	N	7	N	H	C	10	75	RW	BN	Y	60	48	RW	BN	Y
02	C	1	T	3	N	7	N	H	C	20	98	RW	BN	Y	10	10	RW	BN	Y
02	C	2	T	3	N	7	N	H	C	20	87	RW	BN	Y	20	15	RW	BN	Y
02	C	3	T	3	N	7	N	H	C	20	91	RW	BN	Y	60	29	RW	BN	Y
03	C	1	T	3	N	0	N	H	U	1.3	93	RW	BF	Y	10	33	RW	BF	Y
03	C	2	T	3	N	0	N	H	U	1.3	96	RW	BF	Y	20	40	RW	BF	Y
03	C	3	T	3	N	0	N	H	U	1.3	93	RW	BF	Y	60	62	RW	BF	Y
03	C	1	T	3	N	0	N	H	U	5	100	RW	BF	Y	10	30	RW	BF	Y
03	C	2	T	3	N	0	N	H	U	5	95	RW	BF	Y	20	41	RW	BF	Y
03	C	3	T	3	N	0	N	H	U	5	94	RW	BF	Y	60	53	RW	BF	Y
03	C	1	T	3	N	0	N	H	U	10	95	RW	BF	Y	10	29	RW	BF	Y
03	C	2	T	3	N	0	N	H	U	10	94	RW	BF	Y	20	42	RW	BF	Y
03	C	3	T	3	N	0	N	H	U	10	97	RW	BF	Y	60	47	RW	BF	Y
03	C	1	T	3	N	0	N	H	U	20	97	RW	BF	Y	10	17	RW	BF	Y
03	C	2	T	3	N	0	N	H	U	20	96	RW	BF	Y	20	29	RW	BF	Y
03	C	3	T	3	N	0	N	H	U	20	95	RW	BF	Y	60	54	RW	BF	Y
04	C	1	T	3	N	7	N	H	U	1.3	69	RW	BF	Y	10	11	RW	BF	Y
04	C	2	T	3	N	7	N	H	U	1.3	72	RW	BF	Y	20	46	RW	BF	Y
04	C	3	T	3	N	7	N	H	U	1.3	74	RW	BF	Y	60	56	RW	BF	Y
04	C	1	T	3	N	7	N	H	U	5	78	RW	BF	Y	10	5	RW	BF	Y
04	C	2	T	3	N	7	N	H	U	5	81	RW	BF	Y	20	13	RW	BF	Y
04	C	3	T	3	N	7	N	H	U	5	75	RW	BF	Y	60	35	RW	BF	Y
04	C	1	T	3	N	7	N	H	U	10	39	RW	BF	Y	10	9	RW	BF	Y
04	C	2	T	3	N	7	N	H	U	10	75	RW	BF	Y	20	11	RW	BF	Y
04	C	3	T	3	N	7	N	H	U	10	95	RW	BF	Y	60	46	RW	BF	Y
04	C	1	T	3	N	7	N	H	U	20	78	RW	BF	Y	10	8	RW	BF	Y
04	C	2	T	3	N	7	N	H	U	20	73	RW	BF	Y	20	12	RW	BF	Y
04	C	3	T	3	N	7	N	H	U	20	92	RW	BF	Y	60	45	RW	BF	Y
05	C	1	T	3	N	0	N	S	C	1.3	77	RW	BF	Y	10	5	RW	BW	Y
05	C	2	T	3	N	0	N	S	C	1.3	77	RW	BF	Y	20	14	RW	BW	Y
05	C	3	T	3	N	0	N	S	C	1.3	72	RW	BF	Y	60	37	RW	BW	Y
05	C	4	T	3	N	0	N	S	C	1.3	77	RW	BF	Y	10	64	RW	BW	Y
05	C	1	T	3	N	0	N	S	C	10	74	RW	BF	Y	10	6	RW	BW	Y

05	C	2	T	3	N	C	N	S	C	10	78	RW	3F	Y	20	17	RW	3W	Y
05	C	3	T	3	N	C	N	S	C	10	78	RW	3F	Y	60	35	RW	3W	Y
05	C	1	T	3	N	C	N	S	C	20	78	RW	3F	Y	10	7	RW	3W	Y
05	C	2	T	3	N	C	N	S	C	20	81	RW	3F	Y	20	8	RW	3W	Y
05	C	3	T	3	N	C	N	S	C	20	75	RW	3F	Y	60	32	RW	3W	Y
05	C	4	T	3	N	C	N	S	C	20	75	RW	3F	Y	60	72	RW	3W	Y
06	C	1	T	3	N	7	N	S	C	1.3	55	RW	3N	Y	10	25	RW	3W	Y
06	C	2	T	3	N	7	N	S	C	1.3	62	RW	3N	Y	20	31	RW	3W	Y
06	C	3	T	3	N	7	N	S	C	1.3	61	RW	3N	Y	60	46	RW	3W	Y
06	C	1	T	3	N	7	N	S	C	5	56	RW	3N	Y	10	27	RW	3W	Y
06	C	2	T	3	N	7	N	S	C	5	64	RW	3N	Y	20	17	RW	3W	Y
>06	C	3	T	3	N	7	N	S	C	5	53	RW	3N	Y	60	34	RW	3W	Y
06	C	1	T	3	N	7	N	S	C	10	60	RW	3N	Y	10	30	RW	3W	Y
06	C	2	T	3	N	7	N	S	C	10	63	RW	3N	Y	20	10	RW	3W	Y
06	C	3	T	3	N	7	N	S	C	10	65	RW	3N	Y	60	31	RW	3W	Y
06	C	1	T	3	N	7	N	S	C	20	56	RW	3N	Y	10	3	RW	3W	Y
06	C	2	T	3	N	7	N	S	C	20	60	RW	3N	Y	20	10	RW	3W	Y
06	C	3	T	3	N	7	N	S	C	20	63	RW	3N	Y	60	31	RW	3W	Y
17	C	1	T	3	Y	C	N	H	C	1.3	97	RW	3N	Y	10	3	RW	3N	Y
17	C	2	T	3	Y	C	N	H	C	1.3	104	RW	3N	Y	20	12	RW	3N	Y
17	C	3	T	3	Y	C	N	H	C	1.3	135	RW	3N	Y	60	73	RW	3N	Y
17	C	1	T	3	Y	C	N	H	C	5	113	RW	3N	Y	10	9	RW	3N	Y
17	C	2	T	3	Y	C	N	H	C	5	138	RW	3N	Y	20	29	RW	3N	Y
17	C	3	T	3	Y	C	N	H	C	5	137	RW	3N	Y	60	52	RW	3N	Y
17	C	1	T	3	Y	C	N	H	C	10	110	RW	3N	Y	10	3	RW	3N	Y
17	C	2	T	3	Y	C	N	H	C	10	115	RW	3N	Y	20	17	RW	3N	Y
17	C	3	T	3	Y	C	N	H	C	10	113	RW	3N	Y	60	51	RW	3N	Y
17	C	1	T	3	Y	C	N	H	C	20	112	RW	3N	Y	10	10	RW	3N	Y
17	C	2	T	3	Y	C	N	H	C	20	111	RW	3N	Y	20	7	RW	3N	Y
17	C	3	T	3	Y	C	N	H	C	20	112	RW	3N	Y	60	57	RW	3N	Y
18	C	1	T	3	Y	7	N	H	C	1.3	54	RF	3N	Y	10	31	RF	3N	Y
18	C	2	T	3	Y	7	N	H	C	1.3	49	RF	3N	Y	20	43	RF	3N	Y
18	C	3	T	3	Y	7	N	H	C	1.3	47	RF	3N	Y	60	45	RF	3N	Y
18	C	1	T	3	Y	7	N	H	C	5	61	RF	3N	Y	10	57	RF	3N	Y
18	C	2	T	3	Y	7	N	H	C	5	55	RF	3N	Y	20	37	RF	3N	Y
18	C	3	T	3	Y	7	N	H	C	5	55	RF	3N	Y	60	76	RF	3N	Y
18	C	1	T	3	Y	7	N	H	C	10	54	RF	3N	Y	10	14	RF	3N	Y
18	C	2	T	3	Y	7	N	H	C	10	62	RF	3N	Y	20	43	RF	3N	Y
18	C	3	T	3	Y	7	N	H	C	10	74	RF	3N	Y	60	45	RF	3N	Y
18	C	1	T	3	Y	7	N	H	C	20	70	RF	3N	Y	10	5	RF	3N	Y
18	C	2	T	3	Y	7	N	H	C	20	93	RF	3N	Y	20	13	RF	3N	Y
18	C	3	T	3	Y	7	N	H	C	20	71	RF	3N	Y	60	29	RF	3N	Y
19	C	1	T	3	Y	C	N	H	U	1.3	35	RW	3N	Y	10	18	RW	3N	Y
19	C	2	T	3	Y	C	N	H	U	1.3	93	RW	3N	Y	20	20	RW	3N	Y
19	C	3	T	3	Y	C	N	H	U	1.3	91	RW	3N	Y	60	61	RW	3N	Y
19	C	1	T	3	Y	C	N	H	U	5	94	RW	3N	Y	10	9	RW	3N	Y
19	C	2	T	3	Y	C	N	H	U	5	37	RW	3N	Y	20	10	RW	3N	Y
19	C	3	T	3	Y	C	N	H	U	5	42	RW	3N	Y	60	51	RW	3N	Y
19	C	1	T	3	Y	C	N	H	U	10	33	RW	3N	Y	10	10	RW	3N	Y
19	C	2	T	3	Y	C	N	H	U	10	88	RW	3N	Y	20	13	RW	3N	Y
19	C	3	T	3	Y	C	N	H	U	10	43	RW	3N	Y	60	40	RW	3N	Y
19	C	1	T	3	Y	C	N	H	U	20	92	RW	3N	Y	10	12	RW	3N	Y
19	C	2	T	3	Y	C	N	H	U	20	[illegible]	RW	3N	Y	20	11	RW	3N	Y
19	C	3	T	3	Y	C	N	H	U	20	92	RW	3N	Y	60	57	RW	3N	Y
20	C	1	T	3	Y	7	N	H	U	1.3	51	RW	3N	Y	10	5	RW	3N	Y
20	C	2	T	3	Y	7	N	H	U	1.3	[illegible]	RW	3N	Y	20	17	RW	3N	Y
20	C	3	T	3	Y	7	N	H	U	1.3	64	RW	3N	Y	60	57	RW	3N	Y
20	C	1	T	3	Y	7	N	H	U	5	72	RW	3N	Y	10	4	RW	3N	Y

20	C	2	T	3	Y	7	N	H	U	5	70	RW	3N	Y	20	13	RW	BN	Y
20	C	3	T	3	Y	7	N	H	U	5	73	RW	3N	Y	60	42	RW	9N	Y
20	C	1	T	3	Y	7	N	H	U	10	72	RW	3N	Y	10	3	RW	9N	Y
20	C	2	T	3	Y	7	N	H	U	10	59	RW	3N	Y	20	12	RW	3N	Y
20	C	3	T	3	Y	7	N	H	U	10	71	RW	3N	Y	60	61	RW	3N	Y
20	C	1	T	3	Y	7	N	H	U	20	74	RW	9N	Y	10	3	RW	9N	Y
20	C	2	T	3	Y	7	N	H	U	20	68	RW	8N	Y	20	8	RW	RN	Y
20	C	3	T	3	Y	7	N	H	U	20	75	RW	BN	Y	60	37	RW	9N	Y
21	C	1	T	3	Y	C	N	S	C	1.3	70	RW	3F	Y	10	5	RW	RF	Y
21	C	2	T	3	Y	C	N	S	C	1.3	68	RW	RF	Y	20	8	RW	9F	Y
21	C	3	T	3	Y	C	N	S	C	1.3	68	RW	8F	Y	60	25	RW	BF	Y
21	C	1	T	3	Y	C	N	S	C	5	70	RW	9F	Y	10	4	RW	8F	Y
21	C	2	T	3	Y	C	N	S	C	5	69	RW	3F	Y	20	8	RW	BF	Y
21	C	3	T	3	Y	C	N	S	C	5	71	RW	3F	Y	60	23	RW	8F	Y
21	C	1	T	3	Y	C	N	S	C	10	71	RW	3F	Y	10	3	RW	9F	Y
21	C	2	T	3	Y	C	N	S	C	10	70	RW	3F	Y	20	7	RW	9F	Y
21	C	3	T	3	Y	C	N	S	C	10	70	RW	3F	Y	60	22	RW	9F	Y
21	C	1	T	3	Y	C	N	S	C	20	71	RW	3F	Y	10	4	RW	3F	Y
21	C	2	T	3	Y	C	N	S	C	20	72	RW	9F	Y	20	9	RW	9F	Y
21	C	3	T	3	Y	C	N	S	C	20	72	RW	3F	Y	60	24	RW	9F	Y
22	C	1	T	3	Y	7	N	S	C	1.3	59	RW	3F	Y	10	17	RW	9F	Y
22	C	2	T	3	Y	7	N	S	C	1.3	53	RW	9F	Y	20	33	RW	9F	Y
22	C	3	T	3	Y	7	N	S	C	1.3	51	RW	9F	Y	60	37	RW	9F	Y
22	C	1	T	3	Y	7	N	S	C	5	60	RW	3F	Y	10	5	RW	9F	Y
22	C	2	T	3	Y	7	N	S	C	5	59	RW	9F	Y	20	12	RW	9F	Y
22	C	3	T	3	Y	7	N	S	C	5	57	RW	9F	Y	60	43	RW	9F	Y
22	C	1	T	3	Y	7	N	S	C	10	61	RW	3F	Y	10	7	RW	9F	Y
22	C	2	T	3	Y	7	N	S	C	10	59	RW	3F	Y	20	9	RW	3F	Y
22	C	3	T	3	Y	7	N	S	C	10	57	RW	9F	Y	60	43	RW	9F	Y
22	C	1	T	3	Y	7	N	S	C	20	65	RW	9F	Y	10	5	RW	9F	Y
22	C	2	T	3	Y	7	N	S	C	20	61	RW	9F	Y	20	8	RW	9F	Y
22	C	3	T	3	Y	7	N	S	C	20	59	RW	9F	Y	60	41	RW	9F	Y

01	D	1	T	3	N	C	N	H	C	1.3	83	RW	BN	Y	10	3	RW	BN	Y
01	D	2	T	3	N	C	N	H	C	1.3	79	RW	BN	Y	20	5	RW	BN	Y
01	D	3	T	3	N	C	N	H	C	1.3	64	RW	BN	Y	60	37	RW	BN	Y
01	D	1	T	3	N	C	N	H	C	5	83	RW	BN	Y	10	2	RW	BN	Y
01	D	2	T	3	N	C	N	H	C	5	85	RW	BN	Y	20	5	RW	BN	Y
01	D	3	T	3	N	C	N	H	C	5	71	RW	BN	Y	60	8	RW	BN	Y
01	D	1	T	3	N	C	N	H	C	10	91	RW	BN	Y	10	3	RW	BN	Y
01	D	2	T	3	N	C	N	H	C	10	91	RW	BN	Y	20	4	RW	BN	Y
01	D	3	T	3	N	C	N	H	C	10	83	RW	BN	Y	60	12	RW	BN	Y
01	D	1	T	3	N	C	N	H	C	20	101	RW	BN	Y	10	2	RW	BN	Y
01	D	2	T	3	N	C	N	H	C	20	91	RW	BN	Y	20	5	RW	BN	Y
01	D	3	T	3	N	C	N	H	C	20	88	RW	BN	Y	60	10	RW	BN	Y
02	D	1	T	3	N	7	N	H	C	1.3	56	RW	BN	Y	10	7	RW	BN	Y
02	D	2	T	3	N	7	N	H	C	1.3	72	RW	BN	Y	20	39	RW	BN	Y
02	D	3	T	3	N	7	N	H	C	1.3	57	RW	BN	Y	60	33	RW	BN	Y
02	D	1	T	3	N	7	N	H	C	5	61	RW	BN	Y	10	3	RW	BN	Y
02	D	2	T	3	N	7	N	H	C	5	82	RW	BN	Y	20	7	RW	BN	Y
02	D	3	T	3	N	7	N	H	C	5	59	RW	BN	Y	60	41	RW	BN	Y
02	D	1	T	3	N	7	N	H	C	10	71	RW	BN	Y	20	7	RW	BN	Y
02	D	2	T	3	N	7	N	H	C	10	66	RW	BN	Y	60	53	RW	BN	Y
02	D	1	T	3	N	7	N	H	C	20	73	RW	BN	Y	10	7	RW	BN	Y
02	D	2	T	3	N	7	N	H	C	20	54	RW	BN	Y	20	7	RW	BN	Y
02	D	3	T	3	N	7	N	H	C	20	68	RW	BN	Y	60	14	RW	BN	Y
03	D	1	T	3	N	C	N	H	U	1.3	53	RF	BN	Y	10	8	RF	BN	Y
03	D	2	T	3	N	C	N	H	U	1.3	40	RF	BN	Y	20	5	RF	BN	Y
03	D	3	T	3	N	C	N	H	U	1.3	47	RF	BN	Y	60	37	RF	BN	Y
03	D	1	T	3	N	C	N	H	U	5	58	RF	BN	Y	10	13	RF	BN	Y
03	D	2	T	3	N	C	N	H	U	5	55	RF	BN	Y	20	33	RF	BN	Y
03	D	3	T	3	N	C	N	H	U	5	55	RF	BN	Y	60	22	RF	BN	Y
03	D	1	T	3	N	C	N	H	U	10	57	RF	BN	Y	10	2	RF	BN	Y
03	D	2	T	3	N	C	N	H	U	10	79	RF	BN	Y	20	6	RF	BN	Y
03	D	3	T	3	N	C	N	H	U	10	65	RF	BN	Y	60	11	RF	BN	Y
03	D	1	T	3	N	C	N	H	U	20	59	RF	BN	Y	10	2	RF	BN	Y
03	D	2	T	3	N	C	N	H	U	20	62	RF	BN	Y	20	19	RF	BN	Y
03	D	3	T	3	N	C	N	H	U	20	53	RF	BN	Y	60	8	RF	BN	Y
04	D	1	T	3	N	7	N	H	U	1.3	43	RW	BN	Y	10	7	RW	BN	Y
04	D	2	T	3	N	7	N	H	U	1.3	37	RW	BN	Y	20	5	RW	BN	Y
04	D	3	T	3	N	7	N	H	U	1.3	32	RW	BN	Y	60	43	RW	BN	Y
04	D	1	T	3	N	7	N	H	U	5	42	RW	BN	Y	10	13	RW	BN	Y
04	D	2	T	3	N	7	N	H	U	5	48	RW	BN	Y	20	4	RW	BN	Y
04	D	3	T	3	N	7	N	H	U	5	48	RW	BN	Y	60	11	RW	BN	Y
04	D	1	T	3	N	7	N	H	U	10	47	RW	BN	Y	10	6	RW	BN	Y
04	D	2	T	3	N	7	N	H	U	10	54	RW	BN	Y	20	8	RW	BN	Y
04	D	3	T	3	N	7	N	H	U	10	45	RW	BN	Y	60	13	RW	BN	Y
04	D	1	T	3	N	7	N	H	U	20	52	RW	BN	Y	10	5	RW	BN	Y
04	D	2	T	3	N	7	N	H	U	20	48	RW	BN	Y	20	5	RW	BN	Y
04	D	3	T	3	N	7	N	H	U	20	59	RW	BN	Y	60	13	RW	BN	Y

05	D	1	T	3	N	C	N	S	C	1.3	44	RF	3N	Y	10	34	RW	3N	Y
05	D	2	T	3	N	C	N	S	C	1.3	77	RW	3N	Y	20	12	RW	3N	Y
05	D	3	T	3	N	C	N	S	C	1.3	78	RW	3N	Y	60	23	RW	3N	Y
05	D	1	T	3	N	C	N	S	C	5	36	RW	3N	Y	10	2	RW	3N	Y
05	D	2	T	3	N	C	N	S	C	5	75	RW	3N	Y	20	5	RW	3N	Y
05	D	3	T	3	N	C	N	S	C	5	83	RW	3N	Y	60	10	RW	3N	Y
05	D	1	T	3	N	C	N	S	C	10	37	RW	3N	Y	10	2	RW	3N	Y
05	D	2	T	3	N	C	N	S	C	10	35	RW	3N	Y	20	5	RW	3N	Y
05	D	3	T	3	N	C	N	S	C	10	76	RW	3N	Y	60	10	RW	3N	Y
05	D	1	T	3	N	C	N	S	C	20	81	RW	3N	Y	10	2	RW	3N	Y
05	D	2	T	3	N	C	N	S	C	20	89	RW	3N	Y	20	4	RW	3N	Y
05	D	3	T	3	N	C	N	S	C	20	83	RW	3N	Y	60	9	RW	3N	Y
06	D	1	T	3	N	7	N	S	C	1.3	61	RW	3N	Y	10	3	RW	3N	Y
06	D	2	T	3	N	7	N	S	C	1.3	62	RW	3N	Y	20	10	RW	3N	Y
06	D	3	T	3	N	7	N	S	C	1.3	53	RW	3N	Y	60	18	RW	3N	Y
06	D	1	T	3	N	7	N	S	C	5	56	RW	3N	Y	10	22	RW	3N	Y
06	D	2	T	3	N	7	N	S	C	5	73	RW	3N	Y	20	5	RW	3N	Y
06	D	3	T	3	N	7	N	S	C	5	61	RW	3N	Y	60	15	RW	3N	Y
06	D	1	T	3	N	7	N	S	C	10	71	RW	3N	Y	10	3	RW	3N	Y
06	D	2	T	3	N	7	N	S	C	10	59	RW	3N	Y	20	12	RW	3N	Y
06	D	3	T	3	N	7	N	S	C	10	57	RW	3N	Y	60	13	RW	3N	Y
06	D	1	T	3	N	7	N	S	C	20	82	RW	3N	Y	10	12	RW	3N	Y
06	D	2	T	3	N	7	N	S	C	20	51	RW	3N	Y	20	7	RW	3N	Y
06	D	3	T	3	N	7	N	S	C	20	74	RW	3N	Y	60	23	RW	3N	Y
17	D	1	T	3	Y	C	N	H	C	1.3	59	RW	3N	Y	10	3	RW	3N	Y
17	D	2	T	3	Y	C	N	H	C	1.3	57	RW	3N	Y	20	11	RW	3N	Y
17	D	3	T	3	Y	C	N	H	C	1.3	73	RW	3N	Y	60	16	RW	3N	Y
17	D	1	T	3	Y	C	N	H	C	5	65	RW	3N	Y	10	3	RW	3N	Y
17	D	2	T	3	Y	C	N	H	C	5	67	RW	3N	Y	20	4	RW	3N	Y
17	D	3	T	3	Y	C	N	H	C	5	59	RW	3N	Y	60	18	RW	3N	Y
17	D	1	T	3	Y	C	N	H	C	10	59	RW	3N	Y	10	3	RW	3N	Y
17	D	2	T	3	Y	C	N	H	C	10	74	RW	3N	Y	20	5	RW	3N	Y
17	D	3	T	3	Y	C	N	H	C	10	63	RW	3N	Y	60	13	RW	3N	Y
17	D	1	T	3	Y	C	N	H	C	20	72	RW	3N	Y	10	2	RW	3N	Y
17	D	2	T	3	Y	C	N	H	C	20	75	RW	3N	Y	20	5	RW	3N	Y
17	D	3	T	3	Y	C	N	H	C	20	74	RW	3N	Y	60	14	RW	3N	Y
18	D	1	T	3	Y	7	N	H	C	1.3	47	RW	3N	Y	10	3	RW	3N	Y
18	D	2	T	3	Y	7	N	H	C	1.3	51	RW	3N	Y	20	7	RW	3N	Y
18	D	3	T	3	Y	7	N	H	C	1.3	53	RW	3N	Y	60	23	RW	3N	Y
18	D	1	T	3	Y	7	N	H	C	5	67	RW	3N	Y	10	3	RW	3N	Y
18	D	2	T	3	Y	7	N	H	C	5	55	RW	3N	Y	20	2	RW	3N	Y
18	D	3	T	3	Y	7	N	H	C	5	77	RW	3N	Y	60	15	RW	3N	Y
18	D	1	T	3	Y	7	N	H	C	10	56	RW	3N	Y	10	2	RW	3N	Y
18	D	2	T	3	Y	7	N	H	C	10	62	RW	3N	Y	20	3	RW	3N	Y
18	D	3	T	3	Y	7	N	H	C	10	63	RW	3N	Y	60	11	RW	3N	Y
18	D	1	T	3	Y	7	N	H	C	20	65	RW	3N	Y	10	1	RW	3N	Y
18	D	2	T	3	Y	7	N	H	C	20	74	RW	3N	Y	20	3	RW	3N	Y
18	D	3	T	3	Y	7	N	H	C	20	67	RW	3N	Y	60	9	RW	3N	Y
19	D	1	T	3	Y	C	N	H	U	1.3	45	RW	3N	Y	10	5	RW	3N	Y
19	D	2	T	3	Y	C	N	H	U	1.3	47	RW	3N	Y	20	22	RW	3N	Y
19	D	3	T	3	Y	C	N	H	U	1.3	71	RW	3N	Y	60	41	RW	3N	Y
19	D	1	T	3	Y	C	N	H	U	5	57	RW	3N	Y	10	3	RW	3N	Y

19	D	2	T	3	Y	C	N	H	U	5	46	RW	BN	Y	20	4	RW	BN	Y
19	D	3	T	3	Y	C	N	H	U	5	53	RW	BN	Y	60	18	RW	BN	Y
19	D	1	T	3	Y	C	N	H	U	10	61	RW	BN	Y	10	6	RW	BN	Y
19	D	2	T	3	Y	C	N	H	U	10	52	RW	BN	Y	20	3	RW	BN	Y
19	D	3	T	3	Y	C	N	H	U	10	51	RW	BN	Y	60	16	RW	BN	Y
19	D	1	T	3	Y	C	N	H	U	20	51	RW	BN	Y	10	1	RW	BN	Y
19	D	2	T	3	Y	C	N	H	U	20	57	RW	BN	Y	20	3	RW	BN	Y
19	D	3	T	3	Y	C	N	H	U	20	47	RW	BN	Y	60	15	RW	BN	Y
20	D	2	T	3	Y	7	N	H	U	1.3	24	RF	BN	Y	20	38	RW	BN	Y
20	D	1	T	3	Y	7	N	H	U	1.3	22	RF	BN	Y	10	2	RW	BN	Y
20	D	3	T	3	Y	7	N	H	U	1.3	44	RF	BN	Y	60	42	RW	BN	Y
20	D	1	T	3	Y	7	N	H	U	5	39	RF	BN	Y	10	1	RW	BN	Y
20	D	2	T	3	Y	7	N	H	U	5	45	RF	BN	Y	20	5	RW	BN	Y
20	D	3	T	3	Y	7	N	H	U	5	52	RF	BN	Y	60	14	RW	BN	Y
20	D	1	T	3	Y	7	N	H	U	10	40	RF	BN	Y	10	2	RW	BN	Y
20	D	2	T	3	Y	7	N	H	U	10	36	RF	BN	Y	20	8	RW	BN	Y
20	D	3	T	3	Y	7	N	H	U	10	31	RF	BN	Y	60	34	RW	BN	Y
20	D	1	T	3	Y	7	N	H	U	20	36	RF	BN	Y	10	1	RW	BN	Y
20	D	2	T	3	Y	7	N	H	U	20	44	RF	BN	Y	20	3	RW	BN	Y
20	D	3	T	3	Y	7	N	H	U	20	51	RF	BN	Y	60	19	RW	BN	Y
21	D	1	T	3	Y	C	N	S	C	1.3	32	RW	BN	Y	10	31	RW	BN	Y
21	D	2	T	3	Y	C	N	S	C	1.3	54	RW	BN	Y	20	15	RW	BN	Y
21	D	3	T	3	Y	C	N	S	C	1.3	56	RN	BN	Y	60	28	RW	BF	Y
21	D	1	T	3	Y	C	N	S	C	5	73	RW	BN	Y	10	4	RW	BN	Y
21	D	2	T	3	Y	C	N	S	C	5	66	RW	BN	Y	20	6	RW	BN	Y
21	D	3	T	3	Y	C	N	S	C	5	68	RW	BN	Y	60	15	RW	BF	Y
21	D	1	T	3	Y	C	N	S	C	10	70	RW	BN	Y	10	2	RW	BN	Y
21	D	2	T	3	Y	C	N	S	C	10	71	RW	BN	Y	20	5	RW	BN	Y
21	D	3	T	3	Y	C	N	S	C	10	63	RW	BN	Y	60	20	RW	BF	Y
21	D	1	T	3	Y	C	N	S	C	20	57	RW	BN	Y	10	2	RW	BN	Y
21	D	2	T	3	Y	C	N	S	C	20	71	RW	BN	Y	20	5	RW	BN	Y
21	D	3	T	3	Y	C	N	S	C	20	70	RW	BN	Y	60	27	RW	BF	Y
22	D	1	T	3	Y	7	N	S	C	1.3	52	RW	BN	Y	10	19	RW	BN	Y
22	D	2	T	3	Y	7	N	S	C	1.3	42	RW	BN	Y	20	12	RW	BN	Y
22	D	3	T	3	Y	7	N	S	C	1.3	57	RW	BN	Y	60	31	RW	BF	Y
22	D	1	T	3	Y	7	N	S	C	5	59	RW	BN	Y	10	4	RW	BN	Y
22	D	2	T	3	Y	7	N	S	C	5	58	RW	BN	Y	20	7	RW	BN	Y
22	D	3	T	3	Y	7	N	S	C	5	54	RW	BN	Y	60	25	RW	BF	Y
22	D"	1	T	3	Y	7	N	S	C	10	59	RW	BN	Y	10	4	RW	BN	Y
22	D	2	T	3	Y	7	N	S	C	10	63	RW	BN	Y	20	9	RW	BN	Y
22	D	3	T	3	Y	7	N	S	C	10	65	RW	BN	Y	60	21	RW	BF	Y
22	D	1	T	3	Y	7	N	S	C	20	73	RW	BN	Y	10	15	RW	BN	Y
22	D	2	T	3	Y	7	N	S	C	20	63	RW	BN	Y	20	7	RW	BN	Y
22	D	3	T	3	Y	7	N	S	C	20	78	RW	BN	Y	60	27	RW	BF	Y
25	D	1	T	3	Y	C	W	H	C	1.3	38	RF	BF	Y	10	5	RF	BF	Y
25	D	2	T	3	Y	C	W	H	C	1.3	34	RF	BF	Y	20	15	RF	BF	Y
25	D	3	T	3	Y	C	W	H	C	1.3	53	RF	BF	Y	60	20	RF	BF	Y
25	D	1	1	3	Y	C	W	H	C	5	69	RF	BF	Y	10	3	RF	BF	Y
25	D	2	T	3	Y	C	W	H	C	5	64	RF	BF	Y	20	3	RF	BF	Y
25	D	3	T	3	Y	C	W	H	C	5	49	RF	BF	Y	60	21	RF	BF	Y
25	D	2	T	3	Y	C	W	H	C	10	55	RF	BF	Y	20	5	RF	BF	Y
25	D	3	T	3	Y	C	W	H	C	10	59	RF	BF	Y	60	16	RF	BF	Y
25	D	1	T	3	Y	C	W	H	C	20	48	RF	BF	Y	10	7	RF	BF	Y
25	D	2	T	3	Y	C	W	H	C	20	54	RF	BF	Y	20	4	RF	BF	Y
25	D	3	T	3	Y	C	W	H	C	20	53	RF	BF	Y	60	14	RF	BF	Y
29	D	3	T	3	Y	C	W	S	C	1.3	2	RN	BF	Y	60	61	RF	BF	Y
29	D	2	T	3	Y	C	W	S	C	1.3	1	RN	BF	Y	10	39	RF	BF	Y
29	D	1	T	3	Y	C	W	S	C	5	49	RF	BF	Y	10	2	RF	BF	Y
29	D	2	T	3	Y	C	W	S	C	5	43	RF	BF	Y	60	13	RF	BF	Y
29	D	1	T	3	Y	C	W	S	C	10	51	RF	BF	Y	10	1	RF	BF	Y

29	D	2	T	3	Y	C	W	S	C	10	54	RF	BF	Y	60	15	RF	BF	Y
29	D	1	T	3	Y	C	W	S	C	20	53	RF	BF	Y	10	3	RF	BF	Y
29	D	2	T	3	Y	C	W	S	C	20	50	RF	BF	Y	60	13	RF	BF	Y
01	E	1	T	3	N	C	N	H	C	1.3	115	RW	BN	Y	10	12	RW	BN	Y
01	E	2	T	3	N	C	N	H	C	1.3	119	RW	BN	Y	20	18	RW	BN	Y
01	E	3	T	3	N	C	N	H	C	1.3	104	RW	BN	Y	60	39	RW	BN	Y
01	E	1	T	3	N	C	N	H	C	5	111	RW	BN	Y	10	3	RW	BN	Y
01	E	2	T	3	N	C	N	H	C	5	118	RW	BN	Y	20	9	RW	BN	Y
01	E	3	T	3	N	C	N	H	C	5	108	RW	BN	Y	60	45	RW	BN	Y
01	E	1	T	3	N	C	N	H	C	10	113	RW	BN	Y	10	3	RW	BN	Y
01	E	2	T	3	N	C	N	H	C	10	116	RW	BN	Y	20	13	RW	BN	Y
01	E	3	T	3	N	C	N	H	C	10	119	RW	BN	Y	60	38	RW	BN	Y
01	E	1	T	3	N	C	N	H	C	20	119	RW	BN	Y	10	3	RW	BN	Y
01	E	2	T	3	N	C	N	H	C	20	117	RW	BN	Y	20	7	RW	BN	Y
01	E	3	T	3	N	C	N	H	C	20	117	RW	BN	Y	60	32	RW	BN	Y
02	E	1	T	3	N	7	N	H	C	1.3	68	RW	BN	Y	10	5	RW	BN	Y
02	E	2	T	3	N	7	N	H	C	1.3	47	RW	BN	Y	20	38	RW	BN	Y
02	E	3	T	3	N	7	N	H	C	1.3	65	RW	BN	Y	60	52	RW	BN	Y
02	E	1	T	3	N	7	N	H	C	5	65	RW	BN	Y	10	3	RW	BN	Y
02	E	2	T	3	N	7	N	H	C	5	56	RW	BN	Y	20	16	RW	BN	Y
02	E	3	T	3	N	7	N	H	C	5	77	RW	BN	Y	60	37	RW	BN	Y
02	E	1	T	3	N	7	N	H	C	10	69	RW	BN	Y	10	3	RW	BN	Y
02	E	2	T	3	N	7	N	H	C	10	69	RW	BN	Y	20	9	RW	BN	Y
02	E	3	T	3	N	7	N	H	C	10	82	RW	BN	Y	60	37	RW	BN	Y
02	E	1	T	3	N	7	N	H	C	20	77	RW	BN	Y	10	3	RW	BN	Y
02	E	2	T	3	N	7	N	H	C	20	78	RW	BN	Y	20	10	RW	BN	Y
02	E	3	T	3	N	7	N	H	C	20	69	RW	BN	Y	60	60	RW	BN	Y
03	E	1	T	3	N	C	N	H	U	1.3	66	RF	BN	Y	10	13	RW	BF	Y
03	E	2	T	3	N	C	N	H	U	1.3	67	RF	BN	Y	20	15	RW	BF	Y
03	E	3	T	3	N	C	N	H	U	1.3	57	RF	BN	Y	30	22	RW	BN	Y
03	E	4	T	3	N	C	N	H	U	1.3	69	RF	BN	Y	60	46	RW	BN	Y
03	E	5	T	3	N	C	N	H	U	1.3	65	RF	BN	Y	60	38	RW	BN	Y
03	E	1	T	3	N	C	N	H	U	5	74	RF	BN	Y	10	17	RW	BN	Y
03	E	2	T	3	N	C	N	H	U	5	73	RF	BN	Y	20	24	RW	BN	Y
03	E	3	T	3	N	C	N	H	U	5	72	RF	BN	Y	30	31	RW	BN	Y
03	E	4	T	3	N	C	N	H	U	5	70	RF	BN	Y	60	36	RW	BN	Y
03	E	5	T	3	N	C	N	H	U	5	70	RF	BN	Y	60	37	RW	BN	Y
03	E	1	T	3	N	C	N	H	U	10	75	RF	BN	Y	10	13	RW	BN	Y
03	E	2	T	3	N	C	N	H	U	10	74	RF	BN	Y	20	15	RW	BN	Y
03	E	3	T	3	N	C	N	H	U	10	80	RF	BN	Y	60	30	RW	BN	Y
03	E	1	T	3	N	C	N	H	U	20	89	RF	BN	Y	10	13	RW	BN	Y
03	E	2	T	3	N	C	N	H	U	20	80	RF	BN	Y	20	22	RW	BN	Y
03	E	3	T	3	N	C	N	H	U	20	76	RF	BN	Y	60	33	RW	BN	Y
04	E	1	T	3	N	7	N	H	U	1.3	64	RF	BN	Y	20	22	RW	BN	Y
04	E	2	T	3	N	7	N	H	U	1.3	56	RF	BN	Y	60	54	RW	BN	Y
04	E	1	T	3	N	7	N	H	U	5	62	RF	BN	Y	10	7	RW	BN	Y
04	E	2	T	3	N	7	N	H	U	5	69	RF	BN	Y	20	9	RW	BN	Y
04	E	3	T	3	N	7	N	H	U	5	68	RF	BN	Y	60	38	RW	BN	Y
04	E	1	T	3	N	7	N	H	U	10	74	RF	BN	Y	20	25	RW	BN	Y
04	E	2	T	3	N	7	N	H	U	10	62	RF	BN	Y	60	47	RW	BN	Y
04	E	1	T	3	N	7	N	H	U	20	69	RF	BN	Y	10	5	RW	BN	Y

04	E	2	T	3	N	7	N	H	U	20	78	RF	BN	Y	20	6	RW	BN	Y
04	E	3	T	3	N	7	N	H	U	20	77	RF	BN	Y	60	26	RW	BN	Y
05	E	1	T	3	N	0	N	S	C	1.3	90	RW	BN	Y	10	7	RW	BN	Y
05	E	2	T	3	N	0	N	S	C	1.3	96	RW	BN	Y	20	10	RW	BN	Y
05	E	3	T	3	N	0	N	S	C	1.3	90	RW	BN	Y	60	32	RW	BN	Y
05	E	1	T	3	N	0	N	S	C	5	89	RW	BN	Y	10	7	RW	BN	Y
05	E	2	T	3	N	0	N	S	C	5	93	RW	BN	Y	20	8	RW	BN	Y
05	E	3	T	3	N	0	N	S	C	5	91	RW	BN	Y	60	21	RW	BN	Y
05	E	1	T	3	N	0	N	S	C	10	95	RW	BN	Y	10	4	RW	BN	Y
05	E	2	T	3	N	0	N	S	C	10	90	RW	BN	Y	20	7	RW	BN	Y
05	E	3	T	3	N	0	N	S	C	10	92	RW	BN	Y	60	20	RW	BN	Y
05	E	1	T	3	N	0	N	S	C	20	91	RW	BN	Y	10	4	RW	BN	Y
05	E	2	T	3	N	0	N	S	C	20	91	RW	BN	Y	20	9	RW	BN	Y
05	E	3	T	3	N	0	N	S	C	20	95	RW	BN	Y	60	21	RW	BN	Y
06	E	1	T	3	N	7	N	S	C	1.3	57	RW	BN	Y	20	12	RW	BN	Y
06	E	2	T	3	N	7	N	S	C	1.3	54	RW	BN	Y	60	43	RW	BN	Y
06	E	1	T	3	N	7	N	S	C	5	53	RW	BN	Y	10	5	RW	BN	Y
06	E	2	T	3	N	7	N	S	C	5	52	RW	BN	Y	20	10	RW	BN	Y
06	E	3	T	3	N	7	N	S	C	5	51	RW	BN	Y	60	37	RW	BN	Y
06	E	1	T	3	N	7	N	S	C	10	56	RW	BN	Y	20	8	RW	BN	Y
06	E	2	T	3	N	7	N	S	C	10	57	RW	BN	Y	60	64	RW	BN	Y
06	E	1	T	3	N	7	N	S	C	20	62	RW	BN	Y	10	3	RW	BN	Y
06	E	2	T	3	N	7	N	S	C	20	67	RW	BN	Y	20	9	RW	BN	Y
06	E	3	T	3	N	7	N	S	C	20	55	RW	BN	Y	60	28	RW	BN	Y
17	E	1	T	3	Y	0	N	H	C	1.3	82	RW	BN	Y	10	9	RW	BN	Y
17	E	2	T	3	Y	0	N	H	C	1.3	92	RW	BN	Y	20	25	RW	BN	Y
17	E	3	T	3	Y	0	N	H	C	1.3	90	RW	BN	Y	60	56	RW	BN	Y
17	E	1	T	3	Y	0	N	H	C	5	85	RW	BN	Y	10	4	RW	BN	Y
17	E	2	T	3	Y	0	N	H	C	5	89	RW	BN	Y	20	18	RW	BN	Y
17	E	3	T	3	Y	0	N	H	C	5	98	RW	BN	Y	60	37	RW	BN	Y
17	E	1	T	3	Y	0	N	H	C	10	99	RW	BN	Y	10	5	RW	BN	Y
17	E	2	T	3	Y	0	N	H	C	10	91	RW	BN	Y	20	19	RW	BN	Y
17	E	3	T	3	Y	0	N	H	C	10	98	RW	BN	Y	60	55	RW	BN	Y
17	E	1	T	3	Y	0	N	H	C	20	95	RW	BN	Y	10	3	RW	BN	Y
17	E	2	T	3	Y	0	N	H	C	20	100	RW	BN	Y	20	11	RW	BN	Y
17	E	3	T	3	Y	0	N	H	C	20	96	RW	BN	Y	60	27	RW	BN	Y
18	E	1	T	3	Y	7	N	H	C	1.3	55	RW	BN	Y	10	7	RW	BN	Y
18	E	2	T	3	Y	7	N	H	C	1.3	38	RW	BN	Y	20	13	RW	BN	Y
18	E	3	T	3	Y	7	N	H	C	1.3	43	RF	BN	Y	60	64	RW	BN	Y
18	E	1	T	3	Y	7	N	H	C	5	53	RW	BN	Y	10	4	RW	BN	Y
18	E	2	T	3	Y	7	N	H	C	5	55	RW	BN	Y	20	7	RW	BN	Y
18	E	3	T	3	Y	7	N	H	C	5	37	RW	BN	Y	60	62	RW	BN	Y
18	E	1	T	3	Y	7	N	H	C	10	47	RW	BN	Y	10	4	RW	BN	Y
18	E	2	T	3	Y	7	N	H	C	10	58	RW	BN	Y	20	5	RW	BN	Y
18	E	3	T	3	Y	7	N	H	C	10	57	RW	BN	Y	60	23	RW	BN	Y
18	E	1	T	3	Y	7	N	H	C	20	75	RW	BN	Y	10	3	RW	BN	Y
18	E	2	T	3	Y	7	N	H	C	20	62	RW	BN	Y	20	5	RW	BN	Y
18	E	3	T	3	Y	7	N	H	C	20	64	RW	BN	Y	60	21	RW	BN	Y
19	E	2	T	3	Y	0	N	H	U	1.3	58	RW	BN	Y	20	27	RW	BN	Y
19	E	3	T	3	Y	0	N	H	U	1.3	55	RW	BN	Y	60	50	RW	BN	Y
19	E	1	T	3	Y	0	N	H	U	5	62	RW	BN	Y	10	5	RW	BN	Y
19	E	2	T	3	Y	0	N	H	U	5	64	RW	BN	Y	20	9	RW	BN	Y
19	E	3	T	3	Y	0	N	H	U	5	64	RW	BN	Y	60	38	RW	BN	Y
19	E	2	T	3	Y	0	N	H	U	10	65	RW	BN	Y	20	11	RW	BN	Y
19	E	3	T	3	Y	0	N	H	U	10	65	RW	BN	Y	60	33	RW	BN	Y
19	E	1	T	3	Y	0	N	H	U	20	73	RW	BN	Y	10	8	RW	BN	Y

19	E	2	T	3	Y	6	N	H	U	20	71	RW	BN	Y	20	8	RW	BN	Y
19	E	3	T	3	Y	6	N	H	U	20	75	RW	BN	Y	60	29	RW	BN	Y
20	E	1	T	3	Y	7	N	H	U	1.3	29	RF	BN	Y	10	23	RW	BN	Y
20	E	2	T	3	Y	7	N	H	U	1.3	45	RF	BN	Y	20	23	RW	BN	Y
20	E	3	T	3	Y	7	N	H	U	1.3	45	RF	BN	Y	60	49	RW	BN	Y
20	E	1	T	3	Y	7	N	H	U	5	55	RF	BN	Y	10	9	RW	BN	Y
20	E	2	T	3	Y	7	N	H	U	5	52	RF	BN	Y	20	28	RW	BN	Y
20	E	3	T	3	Y	7	N	H	U	5	50	RF	BN	Y	60	39	RW	BN	Y
20	E	1	T	3	Y	7	N	H	U	10	58	RF	BN	Y	10	5	RW	BN	Y
20	E	2	T	3	Y	7	N	H	U	10	55	RF	BN	Y	20	6	RW	BN	Y
20	E	3	T	3	Y	7	N	H	U	10	59	RF	BN	Y	60	32	RW	BN	Y
20	E	1	T	3	Y	7	N	H	U	20	72	RF	BN	Y	10	13	RW	BN	Y
20	E	2	T	3	Y	7	N	H	U	20	57	RF	BN	Y	20	9	RW	BN	Y
20	E	3	T	3	Y	7	N	H	U	20	64	RF	BN	Y	60	46	RW	BN	Y
21	E	1	T	3	Y	6	N	S	C	1.3	66	RW	BF	Y	10	8	RW	BF	Y
21	E	2	T	3	Y	6	N	S	C	1.3	65	RW	BF	Y	20	22	RW	BF	Y
21	E	3	T	3	Y	6	N	S	C	1.3	53	RW	BF	Y	60	49	RW	BF	Y
21	E	1	T	3	Y	6	N	S	C	5	73	RW	BF	Y	10	5	RW	BF	Y
21	E	2	T	3	Y	6	N	S	C	5	74	RW	BF	Y	20	11	RW	BF	Y
21	E	3	T	3	Y	6	N	S	C	5	74	RW	BF	Y	60	35	RW	BF	Y
21	E	1	T	3	Y	6	N	S	C	10	73	RW	BF	Y	10	6	RW	BF	Y
21	E	2	T	3	Y	6	N	S	C	10	77	RW	BF	Y	20	7	RW	BF	Y
21	E	3	T	3	Y	6	N	S	C	10	79	RW	BF	Y	60	27	RW	BF	Y
21	E	1	T	3	Y	6	N	S	C	20	79	RW	BF	Y	10	2	RW	BF	Y
21	E	2	T	3	Y	6	N	S	C	20	79	RW	BF	Y	20	8	RW	BF	Y
21	E	3	T	3	Y	6	N	S	C	20	82	RW	BF	Y	60	26	RW	BF	Y
22	E	1	T	3	Y	7	N	S	C	1.3	35	RW	BF	Y	10	15	RW	BF	Y
22	E	2	T	3	Y	7	N	S	C	1.3	42	RW	BF	Y	20	21	RW	BF	Y
22	E	3	T	3	Y	7	N	S	C	1.3	33	RW	BF	Y	60	59	RW	BF	Y
22	E	1	T	3	Y	7	N	S	C	5	47	RW	BF	Y	10	23	RW	BF	Y
22	E	2	T	3	Y	7	N	S	C	5	37	RW	BF	Y	20	19	RW	BF	Y
22	E	3	T	3	Y	7	N	S	C	5	50	RW	BF	Y	60	43	RW	BF	Y
22	E	1	T	3	Y	7	N	S	C	10	50	RW	BF	Y	10	4	RW	BF	Y
22	E	2	T	3	Y	7	N	S	C	10	50	RW	BF	Y	20	12	RW	BF	Y
22	E	3	T	3	Y	7	N	S	C	10	54	RW	BF	Y	60	30	RW	BF	Y
22	E	1	T	3	Y	7	N	S	C	20	51	RW	BF	Y	10	3	RW	BF	Y
22	E	2	T	3	Y	7	N	S	C	20	59	RW	BF	Y	20	7	RW	BF	Y
22	F	3	T	3	Y	7	N	S	C	20	59	RW	BF	Y	60	33	RW	BF	Y

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